Document No. FCF-PO-RPT-0003
Revision Initial Release

Fluids and Combustion Facility Document

FCF Software Critical Design Review Board Report

Date: January 6, 2003

Approved by David York, Chief Engineer, Flight Software Engineering Branch, 7750

Distribution:

[ ] NASA (U.S. Gov. Only) [ ] Project Only [x] Government and Contractor

Availability:

[x] Public (No Restriction) [ ] Export Controlled [ ] Confidential/Commercial [ ] Internal Use Only

NASA - Glenn Research Center
Cleveland, OH 44135

Signature Page

(Official signatures on file with the FCF Project Control Specialist)

Prepared and Approved By:

David York, P.E.
Chairperson, FCF SW CDR Board
Chief Engineer, Flight Software Engineering Branch
Engineering and Technical Services Directorate
Glenn Research Center

Change Record

Rev.	Effective Date	Description
Initial Release	1/6/02	Initial Release

TABLE OF CONTENTS

1.0 INTRODUCTION

The International Space Station (ISS) Fluids and Combustion Facility (FCF) is a research facility being developed for permanent installation in the ISS United States Laboratory Module to support sustained, systematic microgravity fluid physics and combustion science experimentation. The facility must meet the envelope of science requirements, be designed for compatibility with various carrier/vehicle requirements and constraints, and support fluids/combustion research utilization needs within the available ISS resources for ten or more years of operation.

The FCF is a unique and highly capable ISS research facility whose completion and operation both on-orbit and on the ground is wanted and needed by the Microgravity Fluid Physics and Combustion Science Programs as an essential element of NASA's Biological and Physical Research (BPR) Enterprise whose goals are outlined in NASA's Strategic Plan. This facility has received strong endorsement from the fluids/combustion international scientific community, where cooperative agreements, including commercial utilization, are already in place. It is evident that there is a very high level of commitment by the Glenn Research Center (GRC) Microgravity Science Division (MSD) to ensure that the successful development and deployment of the FCF will provide the needed capability to the international scientific community and commercial interests.

The FCF is being developed under a completion-type, prime development contract called the Microgravity Research, Development and Operations Contract (MRDOC). The contract scope includes the production, deployment, and operation of the FCF on ISS. Northrop Grumman Information Technology (NGIT) is the prime development contractor. MRDOC Exhibit 1 was recently revised from a Fixed Price Incentive Firm (FPIF) to a Cost Plus Award Fee (CPAF) contract.

The FCF Software Critical Design Review (FCF SW CDR) was a comprehensive process that included an in-depth review of the FCF SW documentation and presentations by a team of experts and representatives from around NASA and their supporting contractors. This team included members from GRC's Engineering and Technical Services (E&TS) Directorate, specifically the Flight Software Engineering Branch (FSEB), the Diagnostics and Data Systems Branch (D&DS), and the Systems Engineering and Integration Branch (SE&I). The team also included members from GRC's Safety and Assurance Technologies Directorate (SATD) and their contractor SAIC; GRC's MSD, specifically Division Management, the Microgravity Science Branch, the ISS Facility Projects Branch, and their contractor Alphaport; and the NGIT sub-contractor for Software Quality Assurance, Hernandez Engineering, Inc. Team members from other NASA Centers and supporting contractors included representation from the Goddard Space Flight Center (GSFC) Software Independent Verification and Validation (IV&V) Facility; Marshall Space Flight Center (MSFC) Operations Control team; Johnson Space Center (JSC) and Boeing ISS Payload Integration team and United Space Alliance (USA) Crew Interfaces team.

The review process is described in the FCF Software Critical Design Review Plan as referenced in the Reference Document section of this report. The scope of the review is described in Section 1.2 of this report. The remainder of this report includes the findings of the Board based upon input from the review process and Board deliberations as well as reference material.

1.1 Membership of the FCF Software CDR Board

The membership of the FCF SW CDR Board was as designated in a Letter of Appointment by the Project Manager (see Appendix A.1).

In November, Gerald Esquival, JSC/OZ, informed the Board Chair that he would be unable to attend and requested that James Cochrane, JSC/OZ, attend in his stead. A revised Letter of Appointment (see Appendix A.2) was issued by the FCF Project Manager to reflect this change.

The Board convened on December 3, 2002 and was informed on that date that James Cochrane would be unable to attend due to an emergency. As a result, JSC was not represented on the Board. However, two JSC/Boeing representatives were in the audience to help with ISS Payload Integration issue.

The final Board membership was as follows:

Chairperson:	David W. York (GRC/7140/7750)
Software Systems Consultant:	Carl J. Daniele (Alphaport, Inc.)
Operations Representative:	Diane C. Malarik (GRC/6724)
FCF SW Oversight Lead:	Joseph G. Ponyik (GRC/7140/7750)
FCF Chief Engineer:	Dennis W. Rohn (GRC/7810)
MSD Representative:	Kathleen E. Schubert (GRC/6700)
SATD Representative:	Phuoc H. Thai (GRC/8100)
Science Representative:	Dr. Karen J. Weiland (GRC/6711)

The following individual served as an ex-officio member of the Board:

SW Independent Assessment:	Marcus S. Fisher, GSFC-IV&V Facility

The Review Board findings are summarized in Section 2.0 – Summary Findings. The reader should be cautioned to not only read the Summary Findings, since many factors were used to arrive at this summary and may not be reflected in the Summary Findings.

The Review Board wishes to recognize and acknowledge the efforts of all who helped make the review a success. Presenters were invariably knowledgeable, open, professional, and courteous in responding to questions and comments from the team and others. Support personnel significantly helped the meeting go smoothly and efficiently. All who participated and/or supported are to be commended.

1.2 Scope

A three-day, Software Critical Design Peer Review was held in Cleveland, Ohio on December 3-5, 2002. The Plan for this review appears in the Applicable Document section of this report.

The following areas were within the scope of the review. (Note that in the following scope “software” refers to both software and firmware):

- Flight software for the CIR, FIR and FCF common hardware and subsystems.
- Ground software for the CIR, FIR and FCF ground infrastructure. For ground software, the review covered: 1) Experiment Development Unit (EDU) and Ground Integration Unit (GIU) software; 2) EDU software for astronaut training for the initial CIR and FIR increments; 3) operations plan and data architecture concept; and 4) high level requirements and major computer software configuration items (CSCI) for the above.

- Software interfaces (i.e., ISS to FCF software interfaces, FCF to payload software interfaces, FCF software internal interfaces, FCF rack-to-rack interfaces, FCF flight to ground software interfaces and graphical user interfaces for astronaut and ground operator personnel).
- Software supporting initial increment operations for the FCF CIR and FIR.
- Support software (e.g., software built/used to support FCF hardware development, test support software, etc.).

The following areas were not within the scope of the review:

- Review of Active Rack Isolation System (ARIS) software, except ARIS to FIR software interfaces and any software required for ARIS that will be resident in FIR avionics.
- Detailed review of software integration and test plans to commence environmental and verification testing of FCF flight and ground systems. Separate Verification and Test Reviews (V&TR) for the CIR and FIR will be held following the FCF software CDR, at which time verification test plans of software (and hardware) subsystems/systems will be reviewed.
- Flight and ground software for FCF sustaining engineering, upgrades, logistics/maintenance and operations after FCF deployment to ISS, and initial increment operation of the CIR and FIR with their initial payloads.
- Payload-specific software and non-FCF software specific to operations control centers (e.g., the NASA Glenn Telescience Support Center, payload experiment remote operations sites, etc.).

1.3 Applicable Documents

Document Number	Document Title
FCF-PO-PLAN-0005	FCF Software Critical Design Review Plan
GRC-W6000.002	GRC Work Instruction, Project Implementation Reviews

1.4 Board Charter

In accordance with Critical Design Review requirements for a Peer Review in the NASA Glenn Project Implementation Review Work Instruction, GRC-W6000.002, and CDR requirements in NAS3-99155, the Review Board's charter for the CDR is as follows:

- Establish that FCF software designs accommodate fluids and combustion science requirements.
- Establish that FCF software designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved.
- Review the results of CIR, FIR, and FCF common subsystem and package engineering model tests with respect to software, and establish that any impacts on the flight or end item software specifications or designs have been addressed.
- Evaluate software interface compatibility between the FCF and the ISS, FCF ground systems and operations control center and FCF payload experiments.
- Review the predicted performance of FCF software, including reliability.
- Evaluate compliance with appropriate software safety and quality requirements, and ensure that safety hazard controls have been identified.
- Evaluate the prime Contractor's plans and readiness to code FCF flight and ground software.
- Evaluate the adequacy of the prime Contractor's approach and overarching plans for FCF software verification, validation and testing (recognizing that detailed review of verification plans/requirements will occur at separate V&TRs).

- Evaluate software graphical user interfaces with respect to applicable human factors requirements. Evaluate the adequacy of the FCF ground software to support operations.
- Assess the prime Contractor's Project Plan, including management plan, organization, work breakdown structure, configuration management approach, software development and management plans, and schedules with respect to software. Evaluate the technical, schedule, and cost risks associated with the FCF software development.
- Independently assess the FCF software development effort and risk, and recommend if additional software assurance efforts are needed to mitigate risk and help to ensure FCF mission success.
- Evaluate action item responses and review item discrepancy dispositions from past FCF reviews related to FCF software.

The Review Board should assess the status of FCF software in accordance with the above, and recommend whether or not the prime Contractor is ready to proceed with flight software coding, integration, and test. The Board should also identify any concerns in FCF software development that should be addressed and recommend any actions that should be taken to enhance the success of the next phase of the project.

In accordance with the above guide, the Review Board shall prepare and submit a summary report of its findings within 30 calendar days following the conclusion of the review. The report should include findings on strengths and weaknesses, recommendations by the Board, and formal Requests for Action (RFAs) resulting from the review.

2.0 SUMMARY FINDINGS

2.1 Executive Summary

The Board has concurred that the Project is ready to proceed to the next phase of flight software coding, integration, and testing. The Project is ready to proceed with the ground software requirements and design after completing appropriate table-top reviews as indicated by the RFA. This concurrence is based on the assumption that the Project and Contractor will follow through on the detailed recommendations and requests for action documented in this report and attachments.

The reader is cautioned that these Summary Findings do not include all the Board's observations and recommendations regarding the status of FCF software/firmware. The reader is advised to study the entire report for a better understanding of the state of FCF software. Additional information is included in the attached, RID disposition database.

2.2 Strengths

The greatest strength of the Contractor is the software/firmware flight and ground teams. The team members are hard-working, enthusiastic, dedicated, cooperative, experienced, and knowledgeable. Some of the developers bring with them invaluable knowledge and experience from prior microgravity combustion and fluid physics experiments which have successfully flown. The software team has been working closely with their hardware counterparts and has a good understanding of the hardware. They have been able to support hardware testing such as in the EMI lab and have not delayed such testing. The team members impressed the Review Team during RID disposition and the Board members during the presentations. They are a good example of the adage, "One of the few assets that appreciate in a company are their people." The Board commends the Contractor for assembling such a team.

Another great strength has been the ability of the Contractor software/firmware teams to produce very innovative designs to meet the technical challenges presented by FCF. In particular, the development of the Base Classes and Serial Data Link stand out.

The Base Classes and associated registry implementation have relieved individual software developers of the drudgery of redeveloping standard code which appears in most real-time, multi-tasking systems. The Base Classes epitomize code reuse. Examples of Base Class functionality include: message handling across the entire system; command and data time-stamping and related handling requirements; application start-up and shut-down; real-time task spawning, priority settings and inter-task communications. Benefits to the Project include the minimization of errors and reduced time for testing and verification. Although out-of-scope for this review, it should be noted that use of the FCF Base Classes will produce equivalent benefits for Module and Experiment software, if used.

The development of the Serial Data Link firmware for high-speed image acquisition and storage is very impressive. This pipelined architecture supports a 64 MB/sec image acquisition rate; piping images through at an astounding rate of one every 9.1 milliseconds! Within this time period through the pipe, the images are reformatted, focused, compressed, analyzed, and pumped out to external memory for disk storage. Further, the Serial Data Link is capable of obtaining images from a variety of sources.

The use of the state-of-the-art, object-oriented approach to the software designs is also a great strength and benefit to the Project. It has been shown that such designs are more robust and easier to troubleshoot than older design methods. It is expected that FCF system reliability, maintainability and usability will greatly benefit by this approach.

Results from end-to-end and package testing, while not complete, did give the Board a level of confidence in the software products.

With some exceptions documented in the Type I RIDs RFA, the Board found that the FCF software will support a wide range of combustion and fluid physics science experiments over the lifetime of the facility.

2.3 Weaknesses

The Board has been diligent to put into place Recommendations and Requests for Action to mitigate the major weaknesses listed here. Additionally, the FCF SW CDR Review team has dispositioned RIDs that also address weaknesses, some of which are listed at a high level here.

The Board found the software schedules to be practically useless as a tool to assess critical path, schedule pressures and conflicts, schedule priorities, and to assess software schedule risks.

The Board found the software configuration management in an unacceptable state. Several RFAs address specific configuration management issues.

The Board also found that there is additional effort required to support the integration of FCF experiment payloads. A weakness has been shown on the part of FCF in failing to proactively develop the requirements and interfaces which will be used by experiment software developers. This interface is complicated by the experiment software co-residing in FCF processors. User manuals are also missing.

Another weakness is related to the operational aspects of the software. Definition of capabilities related to nominal and off-nominal scenarios and on-orbit data management need addressing.

In the opinion of the Board, the software effort has been burdened by being understaffed. As a result, attention to such details as software architecture, configuration management, off-nominal requirements/design, and documentation have suffered.

The software architecture has been presented at a very high level, not at the level expected for a CDR, although details of the architecture are buried in the Interface Control Document (ICD).

A weakness was discovered in that the Contractor had not performed an analysis to identify and mitigate potential risks due to common mode failures in software/firmware.

The quality of certain aspects of the software documentation is poor throughout the software documentation. These aspects include poor traceability of requirements both up and down, incorrect or no decomposition of requirements, missing high level requirements and inaccurate traceability tables. The requirements and design need much improvement to cover off-nominal conditions and safety related functions. Verification plans are too generic. The RIDs should take care of a vast majority of the documentation issues. The Contractor's software team leads show great willingness to straighten out the documentation problems through the RID process.

2.4 Concerns and Recommendations

2.4.1 To Support Board Findings Based On Charter

The following concerns and recommendations are a result of common consensus on issues raised during the Board findings based on the charter; item numbers point to the Findings section of this report.

1. Concern: Item 2b related to missing process for requirement waivers and exceptions.

   Recommendation: The Board recommends that the Contractor should put in place a process for identifying requirements that require waivers or exceptions, and a process to handle such requirement waivers or exceptions. The process should provide for a database of requirements known not to be met by the design or from testing. The database information should include: requirement, waiver or exception sought, date sought, resolution, and resolution date.

2. Concern: Items 3a, 3b, related to concerns about software CSC/CSCI testing on engineering model software and software used for engineering model hardware/software integration tests.

   Recommendation: The Board recommends that the Project have the Contractor create and maintain a list of the software tests listed above, including CM information on the location of the code used during the tests. The purpose of this list is to keep track of the number and type of the tests run and sufficient information to retrieve test plans/results and the code used for the tests.

3. Concern: Item 4a, relating to a demonstration of compatibility for the ISS to FCF interface.

   Recommendation: The Contractor should verify the compatibility of this interface before formal verification testing takes place to avoid the need for costly re-verification.

4. Concern: Item 4d, relating to the CIR/FIR rack interface.

   Recommendation: High level requirements and flow-down to software requirements for this interface are missing. The Contractor should add the appropriate requirements and design to ensure that this interface is well-understood and correctly implemented. This should be done before formal verification testing takes place to avoid the need for schedule costly re-verification.

5. Concern: Item 8b, relating to the group training of the Contractor's software staff in safety related software processing and documentation.

   Recommendation: The Board recommends that the entire Contractor's software development team (flight and ground) attend an approximately two hour long presentation on NASA Software Safety provided by GRC/SATD organization. The purpose of this presentation is to bring the team to the same level of understanding of NASA software safety definitions, activities and processes used during the SW development lifecycle. Further, the teams should perform a software safety analysis to verify that all software safety related requirements, designs, coding, and test plans have been properly identified and documented. Completing this Recommendation will likely close out actions on many safety related RIDs.

6. Concern: Items 10d and 11c relating to the SMDP software product deliveries and auditing of the SMDP to ensure that the plan is properly executed.

   Recommendation: The Board recommends that the SMDP should be updated to address software product deliveries, including plans to maintain a database of planned/actual deliveries by product, customer, and dates. The Board also recommends that the Contractor's Software Quality Assurance (SQA) staff be increased to audit SMDP adherence (the SMDP includes other key areas such as software configuration management). This staffing increase has been recommended already by GRC's SATD.

7. Concern: Item 11c relating to whether additional software assurance efforts are needed to mitigate risk and help ensure FCF mission success. Recommendations address the use of NASA's GSFC IV&V Facility.

   Recommendation: The Board recognizes that the GRC Flight Software Engineering Branch (FSEB) Oversight Team, the GRC SATD Team, the Contractor's SQA Team, and the Contractor's Software Engineering Process Group (SEPG) Team are in place to support FCF software development efforts. These teams are engaged in some, but not all activities, which are required to ensure FCF mission success. Further, all the teams suffer from some level of under-staffing or over-subscription of their respective oversight responsibilities.

   The Board consensus was that the Project should take advantage of the IV&V Facility services to mitigate software risks. Our Board member, Marcus Fisher from the IV&V Facility, recognized that FCF, as a Code-U research Project, is under no obligation to use IV&V Facility services. This is the same position also held by the Project and Code Q. Further, Mr. Fisher did not attempt to coerce the Board or influence the voting related to recommendation of the IV&V services. On the contrary, Mr. Fisher provided the Board with significant, positive inputs on a wide range of Board-debated issues whether related to IV&V or not. The Board appreciates his involvement with the FCF SW CDR process.

   Specifically, the Board generated an RFA for IV&V, dealing with verification of critical requirements and end-to-end interfaces. The Board highly recommends that the IV&V Facility be used to execute the actions on this RFA. This recommendation is based on IV&V Facility's experience, collection of automated tool sets, and knowledgeable project managers. The Board believes that the IV&V Facility can add value to the Project. The Board recommends that the NASA and Contractor Project team leads contact Mr. Fisher to discuss the execution of the RFA: who the IV&V Facility assigned project manager will be, and for each RFA task, the specific costs involved, the estimated start and end dates, estimation on the impact to NGIT resources to support the activity. This discussion should be held as soon as possible as this effort impacts upcoming verification testing.

2.4.2 Elevated From Individual Reports

The following concerns and recommendations are elevated from Individual Board Member Reports after review of these reports by the Board Chairperson. Many concerns and recommendations by individual members are now covered by RIDs, RFAs, and Recommendations above. These concerns and recommendations also represent of consensus developed in deliberations of the Board and Board member reviews of the draft of this report. The reader is also encouraged to review the individual reports as they represent important and diverse viewpoints.

1.8 Concern: Mitigation of risks associated with the Contractor's software staffing.

Recommendation: The Board recommends that the Project and Contractor take appropriate steps to ensure that the software staff is sufficient to support the aggressive software schedule. These steps should include evaluating the possible addition of a software systems engineer, and software test support personnel. An additional step should be an evaluation of separating the functions of software technical lead from a software management lead. Experience has shown that the software management functions involve supporting numerous high priority programmatic efforts to the detriment of high priority technical lead functions (e.g. completion of the software system level requirements and software architecture). The Project and Contractor should also consider transferring staff resources from FIR to CIR activities, and work out overtime and second shift strategies for CY '03. The Project and Contractor should also review human resource strategies to ensure a stable software workforce.

1.9 Concern: There will be a need on the part of the Project and Contractor to prioritize open actions, as well as new RIDs, Board recommendations, and RFAs resulting from this SW CDR.

Recommendation: There will be a lot of activity required to close open actions, as well as new RIDs, Board recommendations, and RFAs resulting from this SW CDR. The Board recommends that the Project and Contractor review the activities necessary and prioritize them before proceeding.

3.0 BOARD FINDINGS BASED ON CHARTER

The FCF SW CDR Board arrived at the following consensus through discussion and "vote," with rationale, for each of the items below; addressing the Charter of the Board as specified in the FCF Project Manager's Letter of Appointment dated November 7th, 2002.

Where Board concerns are raised in the items below, we have identified how such concerns have been addressed, whether in RIDs, RFAs, or as Concerns and Recommendations in the Summary Findings section of this report.

1. Establish if FCF SW architecture and designs will accommodate fluids and combustion science requirements.
   - The Board established the status on this item to be between poor and nominal.
   - Rationale: The package software leads demonstrated knowledge of science requirements in their requirements and design. The end-to-end testing demonstrated many capabilities. The FCF SW ICD lists many of the software architecture (CSC and CSCI intercommunications) interfaces but these interfaces were not presented to the Board at a very high level rather than at the depth normally expected at a CDR. Although the bottoms-up design looks good, there is concern on the part of the Board that not all science requirements may have been properly flowed down to software requirements. A number of RIDs were written to improve traceability, system software requirements, system level requirements, and software architecture.

2. Establish that FCF software designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved:

2a. Risk that designs meet the design requirements defined in the governing specifications:
- The Board established this risk as a nominal to high risk.
- Rationale: The current set of design requirements being met by the design appears satisfactory as they now stand. After the regular presentations, at the request of the Board, the contractor provided the Board with an assessment of which key requirements are being met by each CSCI (December 5, 2002). Further, the end-to-end tests demonstrated many of the key requirements being met by the design. There is concern on the part of the Board, however, that some key design requirements may not be met due to proper decomposition of higher level requirements. The Board recommends that successful closure of RIDs/RFAs will go a long way in mitigating this risk.

2b. Waivers or exceptions have been approved where 2a is not met.
- The Board established the status on this item to be nominal.
- Rationale: Not all the Board members felt that there was much presented which would help them assess the status. Of those Board members commenting on this status, it was felt that NGIT may have some incomplete handle on which requirements need waivers/exceptions. Examples of unmet requirements were presented by NGIT include not fully defining and/or meeting the off-nominal limit checking, not meeting some high data capture rates, and not meeting some image tracking/focusing performance requirements. It is not clear that NGIT has a process in place to identify and process those requirements requiring waivers/exceptions. A recommendation (#1) has been made in the Summary Findings section of this report under “Concerns and Recommendations.”

3. Review the results of CIR, FIR and FCF common subsystem and package engineering model tests with respect to software, and establish that any impacts on the flight or end item software specifications or designs have been addressed:

3a. Based on review of tests performed on engineering model SW for CIR, FIR and FCF common subsystems and packages.
- The Board review established that the tests were nominal to good.
- Rationale: The software CSC/CSCI package testing demonstrated that the Contractor team is likely aware of any impacts. However, there are still some concerns that the testing was not complete (presented evidence of ~ 20% of the CSC/CSCIs actually tested), that test plans/results were not presented and possibly not documented correctly, and that the software being used in these tests was not under formal configuration management. To offset these concerns, a recommendation (#2) has been made in the Summary Findings section of this report under “Concerns and Recommendations.”

3b. Based on review of tests performed during hardware/software integration:
- The Board review established that the tests were poor to nominal.
- Rationale: Like the software testing review rationale in 3a, the hardware/software integration testing demonstrated that the Contractor team is likely aware of any impacts. However, there are some nagging concerns that the testing may have not been complete, that test plans/results were not presented and possibly not documented correctly, and that the software being used in these tests was not under formal configuration management. To offset these concerns, a

recommendation (#2) has been made in the Summary Findings section of this report under "Concerns and Recommendations."

3c. Based on analyses performed:

- The Board established that the analyses were nominal to good.
- Rationale: The analyses presented (and embedded in design documentation) were, for the most part, appropriate for this phase of development especially for the Serial Data Link, processor memory usage and bus bandwidth (data rates). Analyses at the software systems level may be incomplete. There is an RFA to provide a more rigorous analysis of processor (CPU) time utilization.

4. Evaluate software interface compatibility between the FCF and the ISS, FCF ground systems and operations control center and FCF payload experiments, as well as FCF software internal interface compatibility:

4a. Evaluation of FCF to ISS Interfaces:

- The Board evaluated that these interfaces are ready or could be ready in time.
- Rationale: The Contractor software team is cognizant of and understands the interface requirements. The design, including the ICD information, clearly indicates that this interface is well developed. There is sufficient testing time available with the Suitcase Test Environment for Payloads (STEP) and Payload Rack Checkout Unit (PRCU). However, the Board has a concern that the interface compatibility was not actually demonstrated, and may not be completely designed. To offset these concerns, a recommendation (#3) has been made in the Summary Findings section of this report under "Concerns and Recommendations."

4b. Evaluation of FCF On-orbit to FCF ground systems & operations interfaces:

- The Board evaluated that these interfaces may or could be ready in time.
- Rationale: This interface design got a late start, which is not unusual. The overall interface seems well thought out but the details may not be defined. It is difficult, with the material presented, to determine if there is sufficient time to complete this interface. An RFA was generated to address software schedule improvement in general. Improved software schedules resulting from successful completion of the software schedules RFA should help determine whether this interface gets completed in time.

4c. Evaluation of FCF to FCF payload experiments interfaces:

- Board evaluated that these interfaces are not ready but may be ready in time.
- Rationale: This is the most problematic interface and one of the major issues discussed in the Board. While there appears to be a good working relationship between LMM and FCF developers, the relationship between FCF developers and MDCA developers appears almost non-existent. There also appears to be floundering among specific PI experiment software developers regarding interfacing with FCF due to lack of FCF Users' Manuals or lack of unified interface requirements from FCF. This interface is especially complicated because PI software can co-exist in FCF processors (e.g. the FSAP). There appear to be no defined "rules" (documentation) regarding the PI use of the FCF Base Classes, task priority assignments, message formatting, time synchronization, and other important fundamental design issues. Further we anticipate FCF/Payload schedule integration issues, leaving us with serious concerns about whether this interface will be completed in time. Because of our serious concerns, we have written an RFA to address these issues and advise MSD to keep a close eye on the issues raised.

4d. Evaluation of FCF internal interfaces:

- The Board evaluated that these interfaces are ready or could be ready in time.
- Rationale: The Board agreed that based on the level of testing presented, the quality of the individual software package leads, and the state of the ICD, that a timely completion of this interface is practically ensured. Concerns were noted by the Board which include the apparent lack of a CIR/FIR interface requirements definition, missing time order protocols (the order in which events are processed and executed), and possible lack of proper implementation due to some mixed use by presenters of the words “requirements” vs. “design.” To offset some of these concerns, a recommendation (#4) has been made in the Summary Findings section of this report under “Concerns and Recommendations.”

5. Review the predicted performance of FCF software, including reliability, maintainability and usability.

5a. Review of reliability:

- The Board review assessed predicted software reliability to be nominal.
- Rationale: There was evidence of a proactive role on the part of the Contractor’s software developers to address reliability through use of the FMEA, object-oriented design, and implementation of CMM KPAs. However, the Board noted that there was no evidence of an actual reliability evaluation presented. Such an evaluation should include a systems approach to software system reliability. Without requirements definition of fault tolerance and off-nominal conditions, a full assessment of reliability is not possible. Operational profiles and error rates were not addressed. RIDs were dispositioned to fix the requirements definition, design and verification of fault tolerance and off-nominal conditions.

5b. Review of maintainability:

- The Board review assessed predicted software maintainability to be nominal to good.
- Rationale: The use of object-oriented design will improve maintainability as will the tools being used by the Contractor. The Contractor has presented evidence of their well-thought out design capability (with the exception of some firmware) to accept on-orbit software upgrades and bug patches from the ground. Board comments also mentioned the positive use by the Contractor of such tools as “DAVE,” but cautions that the life of such tools may come to an end. There was no evidence of a maintainability analysis. The Board has concerns about the lack of a sustaining engineering plan and users' manuals, as addressed in the Payload Integration RFA. The proper execution of this RFA should resolve these concerns.

5c. Review of usability:

- The Board review assessed predicted software usability to be nominal to good.
- Rationale: The Contractor provided evidence of working closely with the ISS Payload Display Review Team and adherence to standards such as SSP-50313. The object-oriented design and use of Base Classes also improve usability. Concerns related to the lack of users' manuals and concerns about the usability for FCF payloads were addressed in 4c above.

6. Evaluate the prime Contractor’s plans and readiness to code FCF flight and ground software, including software analyses.

6a. Evaluation of readiness to proceed to flight SW coding, integration and testing:
- The Board evaluated that the Contractor is ready or could be ready.
- Rationale: The Board has determined that the Contractor is ready based on design and testing presentations and that nothing critical has surfaced. Cautions were noted however. These cautions included that a full set of requirements and software architectures do not exist, that some higher level requirements maybe missing and that tight schedules will be encountered. The Board has attempted to cover these concerns in the RFAs including RIDs from the Review Team.

6b. Evaluation of readiness to proceed to ground SW coding, integration and testing:
- The Board evaluated that the Contractor may not be ready.
- Rationale: Significant work will be necessary to define a full set of requirements and corresponding design before the ground software is ready for coding. The Board has recommended table-top reviews for ground requirements and design in a Ground Software RFA, and is confident that the Contractor can produce in a timely manner.

6c. As to software analyses, this evaluation was placed under section 3c where it seems more appropriate.

7. Review ground software, support software for hardware testing and interface simulation, operations documentation and information technology (IT) security requirements.

7a. Results of a progress review on ground software:
- The Board review found that the Contractor may or could be ready in time.
- Rationale: Significant progress on ground software has been demonstrated by the Contractor over the last few months, and the Contractor seems to have good knowledge of the functionality required. While it is typical for the ground software to lag flight software at this stage of a project, the Project is advised to follow closely the milestone dates for the table-top reviews documented in the ground software RFA.

7b. Results of a progress review of software support of hardware testing and interface simulation:
- The Board review found that the Contractor could be ready in time.
- Rationale: To date the Contractor's software team has been able to meet hardware testing and interface simulation requests without causing a delay in the testing. There was little in the presentations regarding simulations, stubs or test specific software. No software test requirements seemed to have been generated and scheduled to support hardware testing. The Board concludes that the software support will continue to support hardware testing in a timely manner but care should be taken not to over-burden software teams who must complete flight code and verification testing.

7c. Results of a progress review of operations documentation:
- The Board review found that the Contractor is not but may be ready in time.
- Rationale: This is a problematic area. While some thought has gone into operations concepts, there is still a long way to go. The Board has created a Software Operational Aspects RFA to cover this concern. The Project should see that the RFA is executed correctly and in a timely manner.

7d. Results of a progress review of information technology (IT) security requirements:
- The Board review found that the Contractor is ready or could be ready in time.
- Rationale: The Contractor appears aware of IT security requirements and is taking the proper steps to ensure the designs meet requirements.

8. Evaluate compliance with appropriate software safety and quality requirements. Identify actions to control safety hazards and procedures used during the software development lifecycle to address safety-related commands and data.

8a. Evaluation for compliance with appropriate software safety and quality requirements:
- The Board evaluated that the Contractor's compliance is poor to nominal.
- Rationale: The Contractor has quality requirements in place, and has demonstrated awareness and care in the area of software safety. There are concerns that not all safety requirements including off-nominal fault/failure/error handling are captured or addressed. Compliance to 8719.13A was not addressed. A group of RIDs were dispositioned by the Review Team dealing with software safety. Two RFAs have been generated, one dealing with the verification of critical requirements and one dealing with the end-to end verification of critical interfaces. The successful execution of these two RFAs and the software safety RIDs should provide assurance to the Project that software safety design has met safety requirements.

8b. Evaluation of actions to control of safety hazards and procedures used during the SW development lifecycle to address safety related commands and data.
- The Board evaluated the Contractor's actions as poor to nominal.
- Rationale: The Contractor has extracted safety hazards from the FMEA and hazard reports and has passed the Phase 2 Safety Review. However, there appears to be mixed understanding among the Contractor software CSCI leads regarding the approach to software hazards, procedures, and safety related commands, methods, data, and communications. In addition to the RIDs and RFAs mentioned in 8a above, we have made a further recommendation (#5) in the Summary Findings, Concerns and Recommendations section of this report for joint training of the Contractor's software developers by GRC's SATD.

9. Evaluate the adequacy of the prime Contractor's approach and overarching plans for FCF software verification, validation and testing, including qualification/environmental test plans, test flow, software test plans/procedures and the preparation of any supporting test software or equipment (i.e., recognizing that detailed review of verification plans/requirements will occur at separate V&TRs for the CIR and FIR).

9a. Evaluation of the prime Contractor's approach to verification and validation including qualification and environmental test plans:
- The Board evaluated the Contractor's approach as poor to nominal.
- Rationale: The approach to qualification testing was not well described. There are milestones but there is concern by the Board that schedule pressures will compromise testing. FCF-DOC-1111, FCF Software Development Environment document was not received in time for this Review. A RID, RS-0134, to complete this document ASAP was entered and the action accepted by the Contractor. This RID should be monitored for completion. There is a need to formally configuration manage software used in qualification tests. This CM issue is covered in the Software Configuration Management RFA. When this RFA is completed, covering software used in qualification testing, this issue should be resolved.

9b. Evaluation of the prime Contractor's approach to test plans and procedures including supporting test software and/or equipment:

- The Board felt that we could not evaluate this approach at this time.
- Rationale: There were no presentations or evidence of an approach to test plans and procedures other than very high level, generic descriptions in FCF-PLN-1110, FCF Software Verification and Validation Plan. Several RIDs were introduced to clean up this document.

10. Assess the prime contractor's project plans with respect to software, including organization, work breakdown structure, software/firmware configuration management, software development and management plans, software project metrics and schedules. Evaluate the technical, schedule and cost risks associated with the FCF software development.

10a. Assessment of organization:

- The Board assessed the organization as nominal to good.
- Rationale: The Contractor's software team consists of knowledgeable, dedicated and competent people. Staffing levels are below those expected for a development effort of this type. Organizational improvements could include requirements analysts and software testers. The Board also agreed that a software systems engineer should be added to the team, since a competent, experienced software systems engineer could come up to speed relatively quickly. The Contractor should consider moving some software resources from FIR software to CIR software to meet the tighter schedules. The Board commends the acting software lead, Doug Reese, for stepping up this review very quickly.

10b. Assessment of work breakdown structure (WBS):

- The Board assessed the WBS, based on partial voting, as nominal.
- Rationale: This assessment is based on a very limited response from the Board since nothing of substance on the WBS was presented during this Review. Observations below are based on prior knowledge of the WBS and WBS issues. Ground software was moved to a new WBS, WBS 1.5, during the period when the contract modification ECP-2 was being negotiated; from WBS 1.8, (Flight) Software Development. The initial division caused a functional disconnect to occur between flight and ground development teams. We believe that this disconnect is being successfully repaired. The Contractor management is well advised to quickly settle issues between the two work breakdown structures regarding completion of gray area efforts (such as who documents the sustaining engineering plans) to avoid schedule delays. The way the WBS is structured appears to be primarily to support accounting needs (e.g. where the engineers charge their time). While this type of WBS gives management a good handle on costs, this type of WBS structure can obfuscate schedules. There are over 1900 lines in WBS 1.8. When schedules are laid out, there is much copying and pasting going on, leading to incorrect schedule roll-up. Further, software critical path schedules get buried. Management loses the ability to access realistic schedules. The Board has addressed software schedules in an RFA. The Contractor should examine how to decouple the WBS accounting line items from line item schedules, possibly by laying in schedules only at a higher WBS level.

10c. Assessment of software/firmware configuration management (CM):

- The Board assessed the software CM as very poor to poor.
- Rationale: This is a very problematic issue which caused much discussion and frustration at the Board. The Contractor was allowed to conduct the SW CDR based on a plan to complete the software configuration management plan, acceptable to the Government, by the end of December. Many issues/risks are related to software configuration management and four RFAs have been generated to address the various issues: the first RFA deals with the need for off-site

storage of configuration managed software material; the second RFA deals with the need for a software verification facility manager, likely a configuration management function; the third RFA relates to the need of configuration management of GFE or non-Contractor equipment and simulators; and the fourth RFA, and most important RFA, deals with the completion of an acceptable Configuration Management Plan. The Board was disturbed by Contractor groups debating which group was responsible for the various elements in controlling software and software related products. The Board highly recommends that Government stakeholders and the Contractor stakeholders sit down together in a room and complete this Configuration Management Plan now rather than playing ping-pong with the various drafts and markups. Further delay could adversely affect qualification testing, verification testing, and other critical path schedule items.

10d. Assessment of software management and development plans (SMDP):

- The Board assessed the SMDP as poor to nominal.
- Rationale: This Plan was well written for the development of software but is weak as a software management plan. Examples include lack of discussion on major milestones and deliverables. There is no section in the SMDP dealing specifically with software product deliverables. The roles defined in the SMDP template have been reduced, overloading other software roles. There is concern in the Board that the Contractor's SQA organization does not have the resources to adequately audit the Plan's execution. Software configuration management is a prime example of the Plan's shortcomings in execution. There is also a Board concern that the SMDP does not identify a readily available list of all software product deliverables/dates, available to the Government. To offset these concerns, a recommendation (#6) has been made in the Summary Findings section of this report under "Concerns and Recommendations."

10e. Assessment of the software project metrics:

- The Board assessed the software metrics as nominal to good.
- Rationale: The Board concurred that the metrics collection was positive. However, almost all agreed that collecting metrics begs the question of what will be done with them other than to meet a CMM KPA.

10f. Assessment of software project schedules:

- The Board assessed the software project schedules as very poor to poor.
- Rationale: Software project schedules are very problematic due to coupling with over 1900 lines in WBS 1.8 for accounting purposes. Links are missing; major milestone reviews and preparation times are missing. Lots of schedule copy/paste evident. The schedules are unreliable as a management tool. This major concern is documented in an RFA that will hopefully cleanup the software schedules. This RFA is high priority.

10g. Assessment of technical risks:

- The Board assessed this risk as nominal to high.
- Rationale: Although the software team has a good understanding of the hardware they controlling and the algorithms appear to be understood and tested to some extent, some technical risks are still there. The risks appear to lie at a software systems level where some functionality may be missing, such as in the response to off-nominal conditions. RFAs covering verification testing of critical requirements and interfaces are expected to mitigate these system level risks.

10h. Assessment of schedule risks:

- The Board assessed this risk as very high to high.
- Rationale: The Board views schedule risks as very high due to a lack of useful software schedules, as discussed earlier, Additional factors in assessing the risks include the lack of schedule planning to support package level and integrated hardware verification testing, and the use of unpaid overtime over an extended period. A further concern is that if the software used for package level verification requires patches, there is a high risk that unscheduled re-verification efforts might be encountered. There are strong concerns about enforcing the schedule time allotted (~ six weeks) for software team to perform their tests during the hardware/software integrated system testing period. If this team testing period is not protected from schedule pressures, the on-orbit FCF could fall short of science throughput requirements. The Software Schedule RFA, if properly acted upon as a high priority, will mitigate some of this risk.

10i. Assessment of cost risks:

- The Board assessed this risk as nominal to high.
- Rationale: Cost risk is strongly coupled with schedule risk at this phase of the Project with its size and complexity. The greatest threat is from the costs of retesting, or re-verification, if they become required. Mitigations include overtime or multiple shift strategies and scheduling FIR resources to help with the schedule pressure items on CIR.

11. Independently assess the FCF software development effort and risk, and recommend if additional software assurance efforts are needed to mitigate risk and help to ensure FCF mission success.

11a. Assessment of software development effort:

- The Board assessed the software development effort as nominal to good.
- Rationale: Work has progressed well due to the dedication of the software/firmware developers. They should be commended for proceeding with assumed requirements with prototype design and code rather than sitting around waiting for the requirements to show up from hardware and systems. There is obvious commitment and enthusiasm on the team in spite of the long hours. Further, the development effort has produced some novel, unique and very useful designs. Examples include the real-time base classes and registry system and the extraordinarily fast Serial Data Link.

11b. Assessment of software development risk:

- The Board assessed this risk as nominal to high.
- Rationale: The rationale for this risk assessment was identified in 10g to 10i above.

11c. Assessment of whether additional software assurance efforts are needed to mitigate risk and help ensure FCF mission success:

- The Board assessed the need as nominal.
- Rationale: There is good cooperation currently among developers and oversight groups. There is some question about whether the oversight recommendations are fully acted upon. There is a significant staff shortage, both in the GRC Oversight team, the GRC SQA teams, and the Contractor's SQA team. Mitigation strategy is addressed in #7 in the Summary Findings section of this report under "Concerns and Recommendations."

12. Evaluate action item responses and review item discrepancy dispositions from past FCF reviews related to FCF software.

12a. Evaluation of action item (AIs) responses:

- The Board evaluated the responses as poor to nominal.
- Rationale: Action response to software RFAs has been good. There are other actions which have had sub-nominal response, largely due to the old fixed price culture which effectively built a wall around the Contractor. Recently, responses have been excellent. There is still an open action from the S-POCCB, originally due 5/02 now rescheduled for 1/03.

12b. Evaluation of review item discrepancies (RIDs) responses:

- The Board evaluated the responses as nominal to good.
- Rationale: If one judged response based on the culture of the old, fixed price phase of the contract, this evaluation would be much lower due to the lack of resolution on PDR software RIDs for which little evidence of closure exists. There are a few notable exceptions, including response to a RID to develop the Base Classes. We are much more confident of the Contractor in today's culture will respond well to RIDs and show proper evidence of closure.

4.0 INDIVIDUAL BOARD MEMBER REPORTS

4.1 Carl J. Daniele Report

4.1.1 Summary

I attended the Fluids and Combustion Facility Software CDR as an independent reviewer. The Contractor, Northrop Grumman, did a good job presenting the current state of the software development effort. The project software is in a similar state as the software for other projects that I have been involved with during my career. That state is: the lower level engineering model software, which will be elevated to flight software, is working. The overall systems effort to provide an integrated view of the software working to perform tasks is lagging. The software documentation is lagging both the flight and ground software. The ground software is lagging the flight software. The software development schedule is tight. None of this is unusual.

The problems above, for this project, are mitigated by the dedication and exceptional knowledge of the hardware of the software development team and by the use of Object Oriented Design. The developers know and understand the hardware they must drive, and as such, have forged ahead to develop the related software. Refined requirements, developed by systems engineers will be easily incorporated into the software design. The Board has established both RIDS to documents and RFAs to help define the systems tasks.

Overall, the software team is competent. The project is working to develop the systems requirements. I strongly feel that the project should move into the software development and test phase of the life cycle.

4.1.2 Strengths

The knowledge of the software development team and the use of Object Oriented Design are the strengths of the software development effort. The problems I alluded to in my summary above are serious problems for a project. However, the exceptional capability of the development team provides a high confidence level that the work can be finished on time. The requirements, which have been flowed to the team, have been incorporated into a very good design. A possible problem with this aggressive development is the incorporation of incorrect requirements into the design. However, the use of Object Oriented Design mitigates this problem. The design also incorporates Common Base Classes, which allows all developers to use common software. This technique enables developers to concentrate on the

unique requirements of their CSCIs without a lot of effort expended on common requirements (such as communications). An example of a unique requirement is the need for high-speed frame capture and data processing in real time. The team developed unique algorithms and demonstrated that the algorithms work. This example provides insight into the talent of the software developers. Another strength of the team is the use of personnel with knowledge of combustion and fluids experiments in space. Some of the software developers and Contractor personnel have successfully built and flown experiments on the Space Shuttle. The corporate knowledge of the development, testing, integration with the Shuttle, and flying the experiment contributes to the strength of the team.

4.1.3 Weaknesses

With all projects, there are some weaknesses that need attention. However, I do not feel these weaknesses are with the software development team. The project has a lack of visible Configuration Management processes. The Contractor is behind in both developing and implementing CM. There needs to be much more overall systems analysis on the functionality that must be incorporated into the software. These include operations, off nominal operations, fault tolerance approach, common error handling approach and others. Many of the RIDS and RFAs point to this weakness. There is a need for more software development staff. The Contractor is using an overtime approach to help mitigate this problem; however, the approach may cause problems with the developers. There is a need for better schedules. The schedules in use do not provide visibility into major software development activities, such as reviews and software deliveries to specific tests. There is a Software Verification and Validation Plan with does an excellent job incorporating Software Engineering practices; however, the plan needs to be more explicit on specific FCF testing.

4.1.4 Concerns

My major concern is maintaining the software development staff already in place and providing them assistance as “crunch” time approaches. The staff has a lot of work to do to incorporate all the system requirements that will be developed. Other concerns include the development of the system approach to the various activities that must be developed, the strong CM of the test facilities, and the possibility of a common mode error in the myriad of firmware chips that are prevalent through many of the ORUs in the FCF. These chips are not replaceable on orbit and would require an ORU replacement. The final concern is that there is no current formalized agreement between FCF and the payloads that will utilize it.

4.1.5 Recommendations

My recommendations based on my concerns are as follows. To increase software development staff without causing a cost overrun, move some of the developers from the FIR to the CIR. The software design for both is similar; however, FIR is a year behind CIR on the ISS schedule. This solution provides software, knowledgeable developers to CIR without cost to the project. After CIR delivery, experience gained in building CIR will mitigate loss of personnel for the short time in FIR. The RIDs and RFAs developed by the Board will help mitigate most of the other issues. However, I would recommend that NASA Management pay close attention to the Contractor disposition of these issues. The attention required is a strong management of the Contractor to produce the required information. This should be done using a manager who has authority to require the information at specific due dates. That manager must make sure that more time is not spent discussing the work to be done than is spent doing the work. My final recommendation is for the integration of the payloads into FCF. NASA should set up a management structure, or use what is already in place, to guarantee that the software in FCF and its payloads is integrated and works to produce the experiment. The management should have mission responsibility. The structure should force agreements on interfaces and preside over an integration board, which has authority and demands deliverables. This simple move by NASA can significantly increase the probability of mission success.

4.2 Marcus S. Fisher Report

4.2.1 Summary

Looking over the CDR activities from an assortment of standards and based on my involvement with other CDRs, the FCF software CDR covered the typical topics very well. Splinter discussions were needed to acquire additional detail (e.g., coding standards were not discussed but a tangent discussion revealed the Project is employing the use of a coding/programming standard) and they were greatly supported by all Project members.

As with all CDRs, a few weaknesses surfaced that needs to be brought to the attention of the Project, such as design compliance, feasibility of the schedule, and the overall test strategy. There were numerous strengths that were evident and I only named a few in this report, such as the testing of the engineering models, the reliability, maintainability, and usability approaches. I feel the greatest strength of the CDR was the FCF Project members themselves. Their commitment to this Project became very evident in supporting this CDR.

Two concerns are reported within, along with two recommendations that should not impede the FCF Project from moving forward to the next phase and towards mission success.

4.2.2 Strengths

The following are just a few strengths that I feel surfaced during the CDR:

- The current testing of the engineering models shows that a large percentage of the models and the communication paths between them have been exercised, which reduces the likelihood of any major impacts to the end item specifications or design.
- The reliability of the software is increasing due to (a) the identification of software fault tolerance requirements that resulted from a FMEA, (b) the use of a common set of classes, and (c) the test strategy following a CMM Level 3 testing approach.
- An object oriented approach and employing OTS tools during development will make the software more maintainable.
- The use of standards (e.g., SSP 50313), the Operations Nomenclature and the Payload Display Review Team all aid significantly to the usability of the software.
- The technical prowess and commitment by the FCF Team gave additional confidence that FCF was ready to move on to the next phase.

4.2.3 Weaknesses

The following are a few weaknesses that became evident during the presentations:

- Although the software architectures were discussed, compliance to the software requirements and science requirements were not discussed in any great detail.
- There were a couple agenda items that discussed schedule, however there was not sufficient schedule detail to assess feasibility. A few topics that should have been discussed were the critical path, determining how success oriented the schedule is, available margin, resource conflicts, etc.
- Evaluating test plans and procedures was not in the scope of this CDR and is planned to be reviewed during the Verification and Test Reviews (V&TR). The weakness was that there was no information indicating that an adequate requirements verification approach is planned and can be met by the schedule.

4.2.4 Concerns

There were only two concerns that surfaced during the CDR:

- Given the lack of traceability from the science requirements to the design elements, there is a concern that a science requirement will not get implemented.
- Given the fact that not all of the error/fault handling has been defined there is a concern that the design may not meet all the software fault requirements.

4.2.5 Recommendations

The two recommendations are associated with the two concerns identified above:

- Perform a comprehensive traceability analysis in order to quantify the completeness of the design and how well it complies with the science requirements.
- Ensure the handling of faults/failures and the error detection and correction satisfies the applicable higher-level safety/fault requirements.

4.3 Diane C. Malarik Report

4.3.1 Summary

I was pleased with the overall quality of the Software CDR. I feel the FCF software team did an excellent job of presenting the current software approach and design. They were very open, honest and helpful to the board members, both before and during the review. I find that in general, the SW is at a CDR level and recommend the project move forward with the flight software development.

4.3.2 Strengths

I believe that the software team has developed an innovative design that provides a generous suite of software tools that can likely be combined in a flexible manner to achieve a variety of experimental objectives. The use of base classes has proven to be an efficient and effective approach to the software development. The software team did a good job of testing and demonstrating the core functionality and the software is appropriately mature at this phase of the project. Interfaces between the packages were well documented and tested. The overall software approach appears to maximize the potential of re-use, increase maintainability, and enhance flexibility, which is paramount to a facility with a lifetime expectancy of 15 years. Further, I find that the software team is comprised of a number of high quality, innovative engineers and I am confident that the flight software they are designing will perform well for FCF in the future.

4.3.3 Weaknesses

Configuration Management has been a problem across the entire MRDOC contract, and software is no exception. The lack of a government-approved Software CM Plan, at this late stage, is evidence of issues that reside in the CM organization at NGIT.

I believe that the FCF project does not have a strong systems approach to operations, and this weakness flows down into the software. Package leads can describe the capabilities they have incorporated into their packages, but cannot describe how they are to be used at a system level. I believe that the project suffers due to a lack of a well-documented system-level operations concept for the flight hardware and software.

I recognize a weakness in the software integration efforts between FCF and the payload developers. I don't believe the software team fully understands their responsibilities regarding the integration of payload

developers' software into FCF, as evidenced by a lack of a CIR-MDCA SW ICD, even though both projects are at a CDR level. There has been little to no planning regarding the software integration efforts, beyond allowing for time in the schedule to conduct testing.

The "detailed" software schedules are extremely weak. The tasks are 6 to 12 months in duration, and cannot be used to manage to schedule. Since the project is on an excessively aggressive schedule, the software team needs some useful tools to help manage it. It is clear that they were designed to perform cost accounting, not manage schedule.

4.3.4 Concerns

My main concern centers around the lack of a system-level operations approach to the software. I don't believe the software engineers have adequately flowed down the operationally driven requirements into the requirements documentation and design. Neither the nominal, nor off-nominal operational scenarios have been worked out. Without this, the software requirements cannot be complete.

I am also concerned about the lack of a clear approach to the development of Users' Guides for the flight hardware and software. The responsibility has not been delegated to any particular person or group yet, and I am concerned that the Operations Phase of FCF will be compromised because the operations team does not have adequate documentation to understand how the flight system works.

4.3.5 Recommendations

I recommend that the software team document the operational aspects of the software, confirm their flow down to the appropriate software requirements documents and ensure software developer familiarity with them.

Further, I recommend that the responsibility for Users' Guides be clearly identified, and a preliminary list, of them, and their corresponding scope and purpose, be generated and reviewed by the FCF Operations group.

4.4 Joseph G. Ponyik Report

4.4.1 Summary

The Software Team has made good progress and is hard working. They have a good understanding of the hardware they are dealing with which is a big plus. However, they need more effective management and extra personnel to help get the job done by the CIR Flight Hardware Availability (FHA) date. Up to now, the Software Manager has also been the Technical Lead. Both of these positions are full time jobs. The result has been a lack of a software architecture, too many unplanned activities for the software team such as supporting hardware tests, and not enough effort put into the requirements and design specifications to get them to an adequate level of detail. In order to help the team out, I am recommending the following:

1. The Software Manager and Technical Lead positions be held by different individuals.
2. A Software Testing Team get put in place to plan the activities and offload this burden from the current development team.
3. Schedules be improved to better plan for upcoming work.
4. Look into reorganizing the team by moving FIR personnel to CIR and adding new people to work on FIR SW.

One other area that needs improvement is coordination with Operations and Systems. I am recommending that these two groups start holding regular coordination meetings with software and that Operations and Systems start participating in software inspections.

4.4.2 Strengths

The engineers appear to have a good understanding of the hardware they are dealing with. This is often a difficult aspect for embedded software development.

Inspections are being held although they could use improvement. Better planning is needed. Entrance criteria should be established. Results of previous inspections should be used to enhance the entrance criteria.

Software team members have enthusiasm for the job. They also seem to be working well together.

Software team is willing to work with the government and is open to suggestions.

Software team is using the PRACA system developed by SQA to track software problems early in the development process. This early use helps them get familiar with it and also helps them get used to using it.

4.4.3 Weaknesses

No FCF SW Architecture has been developed yet. Without this big picture of FCF Software, the developers of the individual CSCIs do not have an understanding and written description of where their software fits into the system (i.e., how the CSCIs are to work together). They may have their own idea of where and how their software fits in but it is important to get it down on paper so everyone agrees and understands.

Schedules are not adequate. Too many activities occur which are not planned for and result in major blocks of time requiring support from the software team. An example of this is the various package tests that have been performed which tied up many of the software engineers for days at a time which hadn't been planned. Part of the problem lies in the scheduling of the tests which is not well done by groups outside of software. The other problem is that the software schedules do not account for this activity.

Requirements and design are not detailed enough. This causes 3 major problems:

1. It is difficult to detect defects early in the life cycle where they are cheaper to remove.
2. It is difficult to ensure that testing is comprehensive.
3. It is difficult to determine if software meets system and science requirements.

4.4.4 Concerns

Team size does not appear to be adequate to get the job done in time for a January 2004 FHA. This is causing the software team to work too many hours. With major testing coming up, there is more work to be done in the next year than was done this year and the team is getting smaller.

There does not appear to be enough coordination with Operations and Systems.

There is no full-time technical lead for FCF Software.

4.4.5 Recommendations

Even though there is concern about new hires getting up to speed at this stage of the project, a software testing group is needed ASAP. The current strategy of having one or two people responsible for the testing of code they developed is very risky for a project of this size. In addition, the upcoming V&TR will place more demand on their time and delay development. Software test planning has been delayed too long. Suggest adding a software testing team to plan and perform software testing and integration to offload this work from the developers. Also, the contractor should look into the possibility of moving personnel from FIR software to CIR software and hiring new people to work on the FIR software since it has a later FHA date.

Coordination meetings between Software, Operations, and Systems need to be held on a regular basis so that the software being built will be what FCF needs. Operations and Systems should also be involved in the inspections of requirements and design documents.

Up to now, the Technical Lead has also been the Software Manager. The demands of being the Manager have caused the development of the architecture to be delayed. Suggest making one of the existing members a Technical Lead and bringing on a new Software Manager.

4.5 Dennis W. Rohn Report

4.5.1 Summary

Overall, the software design appears to be in good shape if it only needs to meet the documented requirements. The primary concerns are associated with making sure that all requirements have been defined. The area that appears to need the most work is at the system level looking across the CSCIs, outside of FCF to ISS and payloads, and in the processes and planning. If these can be defined quickly, with the dedication and skill of the staff, it appears reasonable that the software will be able to meet the FCF schedule and fully support necessary operations. To do this quickly will require staff augmentation and intensive effort.

While the ground software is not at the same level as the flight software, it appears that it can catch up and be ready, however, it needs further scrutiny and effort.

4.5.2 Strengths

I was impressed with the software development personnel. The staff seemed to be extremely skilled and dedicated to accomplishing the work. This was evidenced by the fact that they made significant progress, even though there were difficulties in identifying detailed requirements. Many times you hear software developers complaining about not getting the information they need from the hardware developers. This was not evident at all during this review and in fact it seemed like the software developers put extra effort into making sure they understood the hardware that their software was loaded on. They were also extremely cognizant of the software that they were developing and its development status.

4.5.3 Weaknesses

There were several weaknesses associated with requirements. It was not evident that the software, as a system, has been assessed for compliance against system level requirements. For example, FCF-SPC-0001 contains a section on Computer Resource Requirements. No/not enough evidence was provided to allow me to make an assessment and no self assessment was provided. The second requirements item deals with the operational aspects (or system view) of the software system. While each CSCI taken alone might meet the defined requirements, it was not apparent that a system view was taken. How the flight CSCIs “play” together, with ISS, with the payload CSCIs and with the ground systems did not seem to be taken in to account. The CSCIs may have the capability to accomplish

something, but it was not clear if use of that capability was part of planned operations or not. One example would be the updating of software. It was clear that it could be uplinked, flown up on a CD and installed from a laptop, or flown up on a replacement FIOP hard drive, but no one was able to stand up and say when each method would be utilized and how it would be selected. In this same example, it did not sound like the software was optimized to make use of the uplink method due to limitations that were not known by the software developers. The third requirement item was that software requirements imposed on payloads and an under standing of the interface information needed to be gathered from payloads seemed to be lacking.

I believe that it is also a severe weakness that the Software CM Plan has not been baselined and approved by the government.

The last weakness is that the CDR did not seem to cover software required to support crew training. This software may be needed at the same time as the flight software and will need to be a unique design/build, in order to simulate the FCF operations completely on the laptop.

Ground Software is not at a CDR level of maturity in definition or design.

4.5.4 Concerns

I had several concerns, not necessarily listed in a priority order:

- It appeared that the contractor was moving forward to reach CMM Level 3 for all KPAs, yet the timeframe to benefit from some of the KPAs has passed. Is this the best approach?
- There are also a number of open items (RIDs; SQA audit findings; concerns stemming from the documentation review, ref. page 36 of GRC presentation; End-phase safety analyses, ref. page 53 of GRC presentation) that need to be followed through on to make sure that they do not fall though the cracks due to schedule and quantity of work. It was stated that final software verification of ISS interfaces cannot be done until FCF is at KSC, this is a risk.
- Not having a baselined, approved CM Plan puts software at risk and may result in loss of necessary information.
- Without payload interface requirement, they may be over or under (more likely) designing their software interface to FCF, and as a minimum, expending more effort than they should have to.
- It does not seem that there is enough time to complete the linking and traceability of all software requirements prior to the V&TR.
- The plan is currently for unbaselined software to be used during flight package level verification testing. There are two concerns with this: 1) Without controls in place, there will be no method/process to evaluate if subsequent changes invalidate verifications already performed. 2) Even if the first concern is taken care of, because software will not be fully mature at the time of package verification, there is a high risk that some verifications will be invalidated due to necessary software changes.

4.5.5 Recommendations

There are several recommendations:

- Evaluate CMM Level 3 KPAs and only work toward those that still have benefit to FCF. This could save manpower and dollars.
- Certainly the open items that were mentioned in the concerns need to be completed
- It is strongly recommended that an individual be identified to be a “systems” engineer for software to look at/work system requirements, operations, payload interfaces/requirements, etc. The individual

should be dedicated to this activity alone and not have other responsibilities. This is also recommended in an RFA.

- Develop a process such that all software changes following the use of that software during a package verification test are evaluated to determine if verifications were invalidated. Also investigate if there is any mitigation that can be done to avoid invalidation of verifications. (RFA written)
- Begin immediately to define the software requirements that FCF should impose on payload developers, including any programmatically imposed requirements, and the information necessary to be gathered from the payloads to fully define the interface. (RFA written)
- Put as much effort as possible in defining the nominal and off nominal operations so that the software is capable of meeting all needs; this includes responses to measurement values and SEE mitigations. (RFA written)
- Assess if there are any actions that can be taken to mitigate the fact that final verification will not occur until FCF is at KSC.
- Provide some sort of review of the ground software at an appropriate time to assure that its requirements have been fully defined; it has been designed to a CDR level, and is ready to be developed/procured.

4.6 Kathleen E. Schubert Report

4.6.1 Summary

This summary documents my individual inputs for the FCF SW CDR held December 3-5, 2002. This is in addition to the panel's final report and specific RFAs submitted and does not repeat the items discussed by the collective products generated by the panel. So, to summarize, I was very impressed by the FCF Software Teams' knowledge and expertise in both hardware functionality and software development. In addition, I commend the Project on holding a separate review to address the design status of just the software. This reflects their recognition of the importance and criticality of the software development effort. Overall, the development team did an excellent job preparing for the review and I commend the team for their diligent work in preparing and executing the SW CDR.

4.6.2 Strengths

The SW Development Team demonstrated tangible evidence of the maturity of the software development and design effort. Designing, coding, and testing the software on engineering model hardware is a definite strength. The developers showed in-depth knowledge of the software design and hardware functionality. The design appears to be complete for nominal operations. The use of common software, object oriented design, and coding standards are all strengths. Also, a working level of interaction and communication with the LMM project was clearly evident during the review.

4.6.3 Weaknesses

The maturity and completeness of the project documentation is lagging the actual software development. In addition, key project management weaknesses with the schedule, plans, and processes were noted in the RFAs. The lack of a SW CM Plan and procedures places the project at risk for being able to actually implement the plan without impacting the development schedule. At the design level, detailed information ranging from individual task priorities and scheduling to interface specifications was not shown

4.6.4 Concerns

The interfaces to the multi-user hardware (LMM and MDCA) and software are a particular concern that the project needs to focus on. The success of the FCF will depend upon its ability to integrate and operate as a system with transparent interfaces to LMM, MDCA, and future PI hardware. Although

guidelines and standards exist for FCF code development they have not been consistently applied to multi-user code development efforts. Across the project, not just software, there is a lack of understanding for how the facility will be operated and how off-nominal events will be handled.

4.6.5 Recommendations

In addition to the RFA actions, I recommend that the project focus on putting in place a useable schedule and software configuration management processes. I expect that the software design details will continue to mature as the software coding efforts continue. I recommend that additional effort be placed on standardizing the use of the FCF coding standards, use of the base class software, and definition of the FCF to multi-user hardware and software interfaces across the FCF and the multi-user hardware teams. The goal of this is to design and code seamless and transparent operations of the facility and any payload operating in the FCF. In the near term, I recommend that the FCF, LMM, and MDCA software development teams get together for bi-weekly peer reviews to collectively review and exchange low level software development information. As the first set of payloads, with development efforts occurring in parallel with the FCF, this will be critical to establishing the standard for future payload software development activities. Operations of the FCF, the payloads, and the TSC should be handled in a similar peer review manner to develop and document a complete operations concept for the facility, its payloads, and the ground systems that support it.

4.7 Phuoc H. Thai Report

4.7.1 Summary

Overall, the FCF software presented met the intended purpose of the CDR exit requirement. SATD determined that the FCF software is ready to proceed to the next development phase. The FCF SW Team is very competent, dedicated, and willing to get the job done. This quality of work ethic was demonstrated throughout the presentations; especially the SW Quality Assurance organization has performed an outstanding job for getting the FCF SW products for this review with limited resources.

4.7.2 Strengths

The Contractor's software team is very knowledgeable. CSCI developers understand what is required on their part and proactively seeks implementation solutions to problems rather than waiting for the requirements to come.

Mature prototype design for Station Support Computer (SSC) to FCF crew interface software and its GUI demonstrated ease of use.

4.7.3 Weaknesses

There is a lack of strong FCF SW system responsibility to provide guidance and system level decision for CSCI developers.

System level requirement is not as complete as CSCI level requirement and some are not traceable.

Few HW/SW integration tests have been performed. Most tests were to verify hardware functionality rather than SW capability.

There is no guidance or requirement for FCF SW interfaces with experiment payloads. This leaves a wide difference on how payloads interface with FCF and potentially leads to not all FCF-provided services being used.

4.7.4 Concerns

Not all FCF software personnel have the same level of understanding NASA software safety activities and processes. This may lead to inconsistent implementation of software control of safety hazards and procedures for safety related commands and data.

The current FCF Software activities and processes do not meet all the applicable requirements of the NASA Software Safety Standard, NASA-STD-8719.13a (use of this standard is required by the SARG, section 4.2.5 of Exhibits 1 and 3, and the NASA Software Assurance Standard (NASA-STD-2201) for software identified as hazard controls. Identification of software safety requirements is inadequate.

4.7.5 Recommendations

All FCF SW personnel attend a two hour presentation on NASA Software Safety provided by GRC/SATD organization. The purpose of this presentation is to bring the whole FCF SW Team to the same level of understanding of NASA software safety definitions, activities, and processes during the SW development lifecycle.

After attending the presentation, each CSCI developer and FCF software system responsible person performs a SW safety requirement analysis and verifies that all software safety requirements have been identified. Then update appropriate requirement documentation along with implementation strategy.

4.8 Dr. Karen J. Weiland Report

4.8.1 Summary

The presentations were a thorough overview of the software, both flight and ground. The flight software is ready to proceed to the flight coding, verification, and testing phases. The ground software design is behind and may not be ready at this time to proceed to the coding, verification, and testing phases. The flight software has a very high schedule risk at this time.

4.8.2 Strengths

The FCF software team is a group of talented, hard-working people. Each of the presenters was very knowledgeable about their area and hardware package. The effort of the team has been very high. In cases where requirements were not all available, they did significant work on their own initiative. A significant number of package level tests were run. The end to-end systems interface test of the CIR was also run. The end-to-end test exercised gas mixing algorithms, diagnostic packages, commanding, control, and data handling. The success of this test was a confidence builder and showed that many of the science requirements are being met. The team is working to address the RIDs and RFAs from this and previous reviews. The interfaces between FCF and ISS are understood. The use of base classes will reduce errors and promote the reuse of software.

4.8.3 Weaknesses

The schedule risk is very high. Only one month of testing was shown in the top-level schedule. This gives very little time to test all nominal and off-nominal cases, especially those that are safety related. It also gives very little time to respond to problems and re-test. No baselined configuration management plan exists. Key requirements were shown for only a few packages. It is unclear if all the package leads know what the science requirements are. No operational scenarios were presented. It is unclear if FCF knows how the experiments will be operated. No plans on payload integration were presented. The end-to-end systems interface test did not exercise all the communication and interface paths. The on-orbit to ground and operations interfaces and the FCF to payloads interfaces are lagging behind the flight software development. The ground software design is lagging behind also. The FSAP high data rate at

10 kHz can be sustained only for 5 minutes. This is sufficient for the current experiment MOBI that requires a high data rate, it is has data runs of 200 seconds.

4.8.4 Concerns

The schedule risk is very high.

4.8.5 Recommendations

Increase the length of time for testing on the flight hardware to be able to recover from errors and retest.

APPENDIX A - APPOINTMENT LETTERS TO THE REVIEW BOARD

A.1 Original Letter of Appointment to the Review Board

National Aeronautics and
Space Administration

John H. Glenn Research Center
Cleveland, Ohio 44135

Reply to Attn of: 6700 (06-03) November 7, 2002

TO: Distribution

FROM: 6700/Microgravity Science Division

SUBJECT: Appointment of Review Board for the Fluids and Combustion Facility (FCF) Software Critical Design Review (06-03)

The Fluids and Combustion Facility (FCF) Software Critical Design Review (CDR) is scheduled on December 3-5, 2002 at the Northrop Grumman Information Technology (NGIT) Building, Room 175, in the Aerospace Parkway adjacent to the NASA Glenn Research Center. The software review will occur on December 3rd and 4th. December 5th is reserved for Review Board caucus.

The Review Board for the FCF Software CDR will consist of the following persons:

Chairperson:	David W. York (GRC/7750)
FCF Software Oversight Lead:	Joseph G. Ponyik (GRC/7750)
FCF Chief Engineer:	Dennis Rohn (GRC/7810)
Science Representative:	Karen Weiland (GRC/6711)
Alt. Science Representative:	Myron Hill (GRC/6712)
Safety/Assurance Representative:	Phuoc Thai (GRC/0510)
Software Systems:	Carl J. Daniele (Alphaport)
Operations Representative:	Diane C. Malarik (GRC/6724)
MSD Representative:	Kathleen E. Schubert (GRC/6700)
ISS SW PE&I Representative:	Gerald Esquivel (JSC/OZ)

The following individuals will serve as ex-officio members of the Review Board.

Software Independent Assessment:	Marcus Fisher (NASA IV&V Facility)

The Software CDR will consist of a review of flight and ground software for the FCF Fluids Integrated Rack (FIR) and Combustion Integrated Rack (CIR). The review will be conducted according to the FCF Software Critical Design Review Plan, FCF-PO-PLAN-0005, dated October 21, 2002, and in accordance with Glenn Research Center (GRC) Work Instruction, GRC-W6000.002, Project

Re: 06-03
November 7, 2002

Implementation Reviews. The FCF Software CDR is designated as a "Peer Design Review", as described in this Work Instruction.

The purpose of the CDR is to determine if the flight and ground software being developed for the FCF satisfies design and functional requirements established in governing specifications and to determine if the requirements and design are sufficient for FCF flight and ground software coding, testing, and verification/validation to proceed with acceptable risk. The CDR will be a complete and comprehensive review of the entire software design and development effort for the FCF project, including government-furnished or contractor-developed software, commercial-off-the-shelf (COTS) software, government-furnished or contractor-developed firmware and COTS firmware. The review will be presented by Northrop Grumman Information Technology (NGIT), who is responsible for FCF's development under Exhibit 1 of the Microgravity Research, Development and Operations Contract (MRDOC), and select government personnel responsible for software oversight of this prime development contract.
The following are within the scope of the review at the FCF Software CDR. (Note that in the following scope and charter definition for the CDR, "software" refers to both software and firmware).

- Flight software for the CIR, FIR and FCF common hardware and subsystems.
- Ground software for the CIR, FIR and FCF ground infrastructure. For ground software, the review will cover; 1) Experiment Development Unit (EDU) and Ground Integration Unit (GIU) software, 2) EDU software for astronaut training for the initial CIR and FIR increments, 3) operations plan and data architecture concept, and 4) high level requirements and major computer software configuration items (CSCI) for the above.
- Software interfaces (i.e., ISS to FCF software interfaces, FCF to payload software interfaces, FCF software internal interfaces, FCF rack-to-rack interfaces, FCF flight to ground software interfaces and graphical user interfaces for astronaut and ground operator personnel).
- Software required to support initial increment operations for the FCF CIR and FIR.
- Support software (e.g., software built/used to support FCF hardware development, test support software, etc.).

Re: 06-03
November 7, 2002

The following areas are not within the scope of the review at the FCF Software CDR.

- Review of Active Rack Isolation System (ARIS) software, except ARIS to FIR software interfaces and any software required for ARIS that will be resident in FIR avionics.
- Detailed review of software integration and test plans to commence environmental and verification testing of FCF flight and ground systems. Separate Verification and Test Reviews (V&TR) for the CIR and FIR will be held following the FCF software CDR, at which time verification test plans of software (and hardware) subsystems/systems will be reviewed.
- Flight and ground software for FCF sustaining engineering, upgrades, logistics/maintenance and operations after FCF deployment to ISS and initial increment operation of the CIR and FIR with their initial payloads.
- Payload-specific software and non-FCF software specific to operations control centers (e.g., the NASA Glenn Telescience Support Center, payload experiment remote operations sites, etc.).

In accordance with Critical Design Review requirements for a Peer Review in the NASA Glenn Project Implementation Review Work Instruction, GRC-W6000.002, and CDR requirements in NAS3-99155, the Review Board's charter for the CDR is as follows:

- Establish that FCF software architecture and designs accommodate fluids and combustion science requirements.
- Establish that FCF software designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved.
- Review the results of CIR, FIR and FCF common subsystem and package engineering model software and hardware/software integration tests, and establish that any impacts on the flight or end item software specifications or designs have been addressed.
- Evaluate software interface compatibility between the FCF and the International Space Station (ISS), FCF ground systems and operations control center and FCF payload experiments, as well as FCF software internal interface compatibility.
- Review the predicted performance of FCF software, including reliability, maintainability and usability.
- Evaluate the prime Contractor's plans and readiness to code FCF flight and ground software, including software analyses.

Re: 06-03
November 7, 2002

- Review ground software, support software for hardware testing and interface simulation, operations documentation and information technology (IT) security requirements.
- Evaluate compliance with appropriate software safety and quality requirements. Identify actions to control safety hazards and procedures used during the software development lifecycle to address safety-related commands and data.
- Evaluate the adequacy of the prime Contractor's approach and overarching plans for FCF software verification, validation and testing, including qualification/environmental test plans, test flow, software test plans/procedures and the preparation of any supporting test software or equipment (i.e., recognizing that detailed review of verification plans/requirements will occur at separate V&TRs for the CIR and FIR).
- Assess the prime contractor's project plans with respect to software, including organization, work breakdown structure, software/firmware configuration management, software development and management plans, software project metrics and schedules. Evaluate the technical, schedule and cost risks associated with the FCF software development.
- Independently assess the FCF software development effort and risk, and recommend if additional software assurance efforts are needed to mitigate risk and help to ensure FCF mission success.
- Evaluate action item responses and review item discrepancy dispositions from past FCF reviews related to FCF software.

The Review Board should assess the status of FCF software in accordance with the above, and recommend whether or not the prime Contractor is ready to proceed with flight software coding, integration and test. The Board should also identify any concerns in FCF software development that should be addressed and recommend any actions that should be taken to enhance the success of the next phase of the project.

In accordance with the above guide, the Review Board shall prepare and submit a summary report of its findings within thirty calendar days following the conclusion of the review. The report should include findings on strengths and weaknesses, recommendations by the Board and formal Requests for Action resulting from the review.

Original signed by Robert L. Zurawski on 11/7/02

Robert L. Zurawski
FCF Project Manager

Re: 06-03
November 7, 2002

Distribution:
Alphaport/C. Daniele
NASA/GRC/0510/P. Thai
NASA/GRC/6700/K. Schubert
NASA/GRC/6711/M. Hill
NASA/GRC/6712/K. Weiland
NASA/GRC/6724/D. Malarik
NASA/GRC/7750/J. Ponyik
NASA/GRC/7750/D. York
NASA/GRC/7810/D. Rohn
NASA IV&V Facility/M. Fisher
NASA/JSC/OZ/G. Esquivel

cc:
NASA GRC/6700/ZIN/D. Sedlak
NASA GRC/6700/ZIN/A. Wood
NASA GRC/MRDOC CM File/D. Davis
NASA GRC/6701/ANLX/V. Portaro
NASA/GRC/0500/K. Adams
NASA/GRC/0510/G. Kelm
NASA/GRC/0510/F. Robinson
NASA/GRC/0520/J. Reagan
NASA/GRC/0520/B. Patel
NASA/GRC/0612/K. Brocone
NASA/GRC/6700/R. Corban
NASA/GRC/6700/F. Kohl
NASA/GRC/6700/J. Salzman
NASA/GRC/6700/S. Simons
NASA/GRC/6700/T. Sutliff
NASA/GRC/6700/J. Wanhainen
NASA/GRC/6700/R. Zurawski
NASA/GRC/6724/F. Gati
NASA/GRC/6724/J. Haggard
NASA/GRC/6724/R. Lauver
NASA/GRC/6724/X. Nguyen
NASA/GRC/6724/T. O'Malley
NASA/GRC/6724/B. Quigley
NASA/GRC/6724/T. St. Onge
NAS/GRC/6728/S. Motil
NASA/GRC/6728/N. Shaw
NASA/GRC/6729/C. Myhre
NASA/GRC/6729/A. Otero
NASA/GRC/7700/J. Taylor

Re: 06-03
November 7, 2002

cc:
NASA/GRC/7715/T. Ruffner
NASA/GRC/7715/J. Thomas
NASA/GRC/7750/K. Carmichael
NASA/GRC/7750/K. Gumto
NASA/GRC/7750/M. Mackin
NASA/GRC/7750/L. Maynard-Nelson
NASA/GRC/7750/P. Mellor
NASA/GRC/7750/L. Van Der Arr
NASA/GRC/7750/D. Varga
NASA HQ/QS/M. Wetherholt
NASA HQ/UG/J. Robey
NASA HQ/UG/B. Carpenter
NASA IV&V Facility/J. Marinaro
NASA MSFC/SD11/TBE/J. Sykes
NASA/JSC/OZ/M. Miller
NASA/JSC/OZ/D. Hartman
NASA JSC/OZ2/USA/J. Temple
NGIT/G. Doerre
NGIT/S. Dudek
NGIT/A. Peddie
NGIT/B. Finley
NGIT/M. Johanson
NGIT/S. Lux
NGIT/T. Wasserbauer
NGIT/ANLX/M. O'Toole
NGIT/N. Bozzolo
NGIT/J. McDade
NGIT/HEI/T. Johnson

A.2 Revised Letter of Appointment to the Review Board

National Aeronautics and
Space Administration

John H. Glenn Research Center
Cleveland, Ohio 44135

Reply to Attn of: 6700 (06-03A) November 26, 2002

TO: Distribution

FROM: 6700/Microgravity Science Division

SUBJECT: Appointment of Review Board for the Fluids and Combustion Facility (FCF) Software Critical Design Review (06-03A)

This memo is revised to change the name of the representative for the JSC Review Board member from Gerald Esquivel to Jim Cochrane as listed below.

The Fluids and Combustion Facility (FCF) Software Critical Design Review (CDR) is scheduled on December 3-5, 2002 at the Northrop Grumman Information Technology (NGIT) Building, Room 175, in the Aerospace Parkway adjacent to the NASA Glenn Research Center. The Review Board for the FCF Software CDR will consist of the following persons:

Chairperson:	David W. York (GRC/7750)
FCF Software Oversight Lead:	Joseph G. Ponyik (GRC/7750)
FCF Chief Engineer:	Dennis Rohn (GRC/7810)
Science Representative:	Karen Weiland (GRC/6711)
Alt. Science Representative:	Myron Hill (GRC/6712)
Safety/Assurance Representative:	Phuoc Thai (GRC/0510)
Software Systems:	Carl J. Daniele (Alphaport)
Operations Representative:	Diane C. Malarik (GRC/6724)
MSD Representative:	Kathleen E. Schubert (GRC/6700)
ISS SW PE&I Representative:	Jim Cochrane (JSC/OZ)

The following individuals will serve as ex-officio members of the Review Board.

Software Independent Assessment:	Marcus Fisher (NASA IV&V Facility)

The Software CDR will consist of a review of flight and ground software for the FCF Fluids Integrated Rack (FIR) and Combustion Integrated Rack (CIR). The review will be conducted according to the FCF Software Critical Design Review Plan, FCF-PO-PLAN-0005, dated October 21, 2002, and in accordance with Glenn Research Center (GRC) Work Instruction, GRC-W6000.002, Project Implementation Reviews. The FCF Software CDR is designated as a “Peer Design Review”, as described in this Work Instruction.

Re: 06-03A
November 26, 2002

The purpose of the CDR is to determine if the flight and ground software being developed for the FCF satisfies design and functional requirements established in governing specifications and to determine if the requirements and design are sufficient for FCF flight and ground software coding, testing, and verification/validation to proceed with acceptable risk. The CDR will be a complete and comprehensive review of the entire software design and development effort for the FCF project, including government-furnished or contractor-developed software, commercial-off-the-shelf (COTS) software, government-furnished or contractor-developed firmware and COTS firmware. The review will be presented by Northrop Grumman Information Technology (NGIT), who is responsible for FCF's development under Exhibit 1 of the Microgravity Research, Development and Operations Contract (MRDOC), and select government personnel responsible for software oversight of this FCF prime development contract.

The following are within the scope of the review at the FCF Software CDR.

- Flight software for the CIR, FIR and FCF common hardware and subsystems
- Ground software for the CIR, FIR and FCF ground infrastructure. The Software CDR will include a review of Experiment Development Unit (EDU) and Ground Integration Unit (GIU) software requirements and design. For the initial CIR and FIR increments, it is planned that the EDU's will be used for astronaut training. Software unique to this training function is within the scope of this review.
- Software interfaces (i.e., ISS to FCF software interfaces, FCF to payload software interfaces, FCF rack-to-rack interfaces, FCF flight to ground software interfaces and graphical user interfaces for astronaut and ground operator personnel).
- Software required to support initial increment operations for the FCF CIR and FIR.
- Support software (e.g., software built/used to support FCF hardware development, test support software, etc.).

The following areas are not within the scope of the review at the FCF Software CDR.

- Review of Active Rack Isolation System (ARIS) software, except ARIS to FIR software interfaces and any software required for ARIS that will be resident in FIR avionics.
- Detailed review of software integration and test plans to commence environmental and verification testing of FCF flight and ground systems. Separate Verification and Test Reviews (V&TR) for the CIR and FIR will be held following the FCF software CDR, at which time verification test plans of software (and hardware) subsystems/systems will be reviewed.

Re: 06-03A
November 26, 2002

- Flight and ground software for FCF sustaining engineering, upgrades, logistics/maintenance and operations after FCF deployment to ISS and initial increment operation of the CIR and FIR with their initial payloads.
- Payload-specific software and software specific to FCF operations control centers (e.g., the NASA Glenn Telescience Support Center, payload experiment remote operations sites, etc.).

In accordance with Critical Design Review requirements for a Peer Review in the NASA Glenn Project Implementation Review Work Instruction, GRC-W6000.002, and CDR requirements in NAS3-99155, the Review Board's charter for the CDR is as follows:

- Establish that FCF software designs accommodate fluids and combustion science requirements.
- Establish that FCF software designs meet, with acceptable risk, the design requirements defined in governing specifications, unless waivers or exceptions have been approved.
- Review the results of CIR, FIR and FCF common subsystem and package engineering model tests with respect to software, and establish that any impacts on the flight or end item software specifications or designs have been addressed.
- Evaluate software interface compatibility between the FCF and the International Space Station (ISS), FCF ground systems and operations control center and FCF payload experiments.
- Review the predicted performance of FCF software, including reliability.
- Evaluate compliance with appropriate software safety and quality requirements, and ensure that safety hazard controls have been identified.
- Evaluate the prime Contractor's plans and readiness to code FCF flight and ground software.
- Evaluate the adequacy of the prime Contractor's approach and overarching plans for FCF software verification, validation and testing (recognizing that detailed review of verification plans/requirements will occur at separate V&TRs).
- Evaluate software graphical user interfaces with respect to applicable human factors requirements. Evaluate the adequacy of the FCF ground software to support operations.
- Assess the prime Contractor's Project Plan, including management plan, organization, work breakdown structure, configuration management approach, software development and management plans, and schedules with respect to software. Evaluate the technical, schedule and cost risks associated with the FCF software development.

Re: 06-03A
November 26, 2002

- Independently assess the FCF software development effort and risk, and recommend if additional software assurance efforts are needed to mitigate risk and help to ensure FCF mission success.
- Evaluate action item responses and review item discrepancy dispositions from past FCF reviews related to FCF software.

The Review Board should assess the status of FCF software in accordance with the above, and recommend whether or not the prime Contractor is ready to proceed with flight software coding, integration and test. The Board should also identify any concerns in FCF software development that should be addressed and recommend any actions that should be taken to enhance the success of the next phase of the project.

In accordance with the above guide, the Review Board shall prepare and submit a summary report of its findings within forty five calendar days following the conclusion of the review. The report should include findings on strengths and weaknesses, recommendations by the Board and formal Requests for Action resulting from the review.

Original signed by Robert L. Zurawski on 11/26/02

Robert L. Zurawski
FCF Project Manager

Distribution:
Alphaport/C. Daniele
NASA/GRC/0510/P. Thai
NASA/GRC/6700/K. Schubert
NASA/GRC/6711/M. Hill
NASA/GRC/6712/K. Weiland
NASA/GRC/6724/D. Malarik
NASA/GRC/7750/J. Ponyik
NASA/GRC/7750/D. York
NASA/GRC/7810/D. Rohn
NASA IV&V Facility/M. Fisher
NASA/JSC/OZ/J. Cochrane

Re: 06-03A
November 26, 2002

cc:
NASA GRC/6700/ZIN/D. Sedlak
NASA GRC/6700/ZIN/A. Wood
NASA GRC/MRDOC CM File/D. Davis
NASA GRC/6701/ANLX/V. Portaro
NASA/GRC/0500/K. Adams
NASA/GRC/0510/G. Kelm
NASA/GRC/0510/F. Robinson
NASA/GRC/0520/J. Reagan
NASA/GRC/0520/B. Patel
NASA/GRC/0612/K. Brocone
NASA/GRC/6700/R. Corban
NASA/GRC/6700/F. Kohl
NASA/GRC/6700/J. Salzman
NASA/GRC/6700/S. Simons
NASA/GRC/6700/T. Sutliff
NASA/GRC/6700/J. Wanhainen
NASA/GRC/6700/R. Zurawski
NASA/GRC/6724/F. Gati
NASA/GRC/6724/J. Haggard
NASA/GRC/6724/R. Lauver
NASA/GRC/6724/X. Nguyen
NASA/GRC/6724/T. O'Malley
NASA/GRC/6724/B. Quigley
NASA/GRC/6724/T. St. Onge
NAS/GRC/6728/S. Motil
NASA/GRC/6728/N. Shaw
NASA/GRC/6729/C. Myhre
NASA/GRC/6729/A. Otero
NASA/GRC/7700/J. Taylor
NASA/GRC/7715/T. Ruffner
NASA/GRC/7715/J. Thomas
NASA/GRC/7750/K. Carmichael
NASA/GRC/7750/K. Gumto
NASA/GRC/7750/M. Mackin
NASA/GRC/7750/L. Maynard-Nelson
NASA/GRC/7750/P. Mellor
NASA/GRC/7750/L. Van Der Arr
NASA/GRC/7750/D. Varga
NASA HQ/QS/M. Wetherholt
NASA HQ/UG/J. Robey
NASA HQ/UG/B. Carpenter

Re: 06-03A
November 26, 2002

cc:
NASA IV&V Facility/J. Marinaro
NASA MSFC/SD11/TBE/J. Sykes
NASA/JSC/OZ/M. Miller
NASA/JSC/OZ/D. Hartman
NASA JSC/OZ2/USA/J. Temple
NGIT/G. Doerre
NGIT/S. Dudek
NGIT/A. Peddie
NGIT/B. Finley
NGIT/M. Johanson
NGIT/S. Lux
NGIT/T. Wasserbauer
NGIT/ANLX/M. O'Toole
NGIT/N. Bozzolo
NGIT/J. McDade
NGIT/HEI/T. Johnson

APPENDIX B - REQUESTS FOR ACTION (RFAs)

FCF-SW-001: Type I RIDs

Statement of Concern

The attached set of Type I RIDs (RIDs containing potential cost impacts greater than $15K and/or RIDs which may impact critical path schedule) impact requirements and design.

These RIDs need to be impacted by the contractor and worked with the government to ensure that the FCF software meets requirements imposed upon it.

Recommended Action

1. Contractor to provide ROM cost/schedule impacts and comments on these RIDs.

2. Government to review results from #1 above.

3. TIM organized with contractor and government to resolve RIDs disposition.

4. Contractor to implement appropriate RID actions and get RID author approval to close RID

5. FCF SW CDR Review Team shall track closure by RID.

6. Report back to Board Chair on dispositions, and, when appropriate, recommend closure.

7. Closure by Project Manager.

8. When all RIDs are successfully closed, this RFA can be closed by the Project Manager.

FCF-SW-002: Type II, III, IV RIDs

Statement of Concern

The attached set of Type II, III, IV RIDs (non-cost impact and non-schedule impact RIDs) have been dispositioned by the FCF-SW CDR Review Team by agreement between the Contractor document author and RID Initiator. These RID actions need to be implemented by the contractor to ensure that FCF software meets the requirements imposed upon it.

Recommended Action

1. Contractor to implement actions, some as modified, recommended by the RID Initiator.

2. Contractor to obtain RID author approval to close RID.

3. FCF software Review Team shall track closure by RID.

4 When all RIDs are successfully closed, this RFA can be closed by the Project Manager.

FCF-SW-003: Payload Software Interface Requirements and Integration

Statement of Concern

1. Requirements have not been imposed on payload software to assure: (a) FCF and payload appear as integrated to ISS; (b) commonality and reusability, which will reduce development cost/schedule; and (c) compatibility with FCF. Also, there is no apparent mechanism to gather information required from payloads needed to "configure" FCF software (e.g., how FCF should respond to a specific signal from a payload).

2. FCF has no documented approach to software integration.

3. There is no baselined CIR-MDCA ICD containing software requirements, yet both projects are at or near CDR.

Recommended Action

1. Develop detailed FCF interface requirements to be imposed on the payload to address the three items listed in the concern. Note that item 3 also includes the aspect of required testing prior to being loaded in/on FCF.

2. Develop a mechanism, such as data table templates, to allow collection of information necessary for payloads to provide to FCF during the engineering/analytical integration phase. This needs to be done as soon as possible, and as a minimum prior to any payload CDR for software. The FCF Project Office and Contractor shall confirm the plan on where this information will be documented.

3. Expand the FCF Ops Plan to include approach to FCF-Payload software integration (processes, roles, responsibilities, configuration management, verification, testing, operations, sustaining engineering, etc.).

4. Baseline the CIR-MDCA software interface requirements as soon as possible.

FCF-SW-004: Disaster recovery from off-site storage

Statement of Concern

The FCF Project products have a high level of complexity, visibility (both internal and external), and development effort. Since there is no off-site storage for these products, the loss and damage to NASA GRC would be high in the event of a disaster.

Recommended Action

The Contractor should investigate and implement off-site storage for all FCF software products. Off-site storage should be secured and accessible. The Contractor may contact GRC for helping to implement this. (Reference Bob Zurawski email cover letter dated 11/1/2002.)

FCF-SW-005: Test strategy

Statement of Concern

The Contractor's software development team is the only entity planning to test the software. Although the CDR information outlined a reasonably good approach, there does not appear to be enough schedule to allow for the review of plans and test procedures (which have not yet been developed). Also, there is no regression test suite yet defined.

Recommended Action

1. Conduct test procedure walk-throughs for those procedures verifying the most critical requirements.
2. Define/develop regression test suite and approach to running it.
3. Develop and distribute the test plans ASAP.
4. Consider alternate team to perform above.

FCF-SW-006: Government Furnished Equipment (GFE) responsibility

Statement of Concern

There is no responsible FCF party and procedure to assure that all GFE and other known non-NGIT equipment and simulators are certified, maintained, updated, and controlled.

Recommended Action

All GFE and other known non-NGIT equipment and simulators are used to support the development of FCF flight and ground software should be placed under CM control.

FCF-SW-007: Configuration Management of test facilities

Statement of Concern

Experience has shown that there needs to be tight CM of test facilities. Without CM, pieces of hardware can be "borrowed" such that V&V of software can be seriously compromised. A change board control is not adequate. Ownership of the facility must be clearly established, as well as how the testing environment is to be controlled and verified.

In the context of this RFA, "test facilities" is defined as any hardware on which software is loaded or tested against for the purpose of software verification and validation. This will include the EM (once it begins to be used for this purpose), flight unit, GIU, PRCU, and STEP.

Recommended Action

For test facilities used for V&V of software, establish a person as facility manager. The facility manager is responsible for making sure that the test facility hardware and software does not change without approval of a governing change control board.

For the test environment, develop test environment plan and the approach to verifying the constituent parts (e.g., models, sims). The Test Environment Plan shall also describe the models and/or sims will be controlled.

FCF-SW-008: Common mode failures

Statement of Concern

Non-reprogrammable firmware (F/W) is located throughout FCF. The F/W cannot be replaced without removing a whole ORU. An error in the F/W can lead to a common mode failure throughout many of the ORUs.

Recommended Action

Through a FMEA or other analysis, all the common F/W components should be identified, such as those in the CAN Bus Processor and the Serial Data Link. Exhaustive testing must be done to verify and validate the F/W. The testing should be done with involvement by all oversight groups such that there is a high degree of certainty that any common mode failure has a very low or zero, probability of occurrence.

FCF-SW-009: Software configuration management

Statement of Concern

1. No government-approved Software Configuration Management (CM) Plan exists.

2. FCF project plans to use non-baselined software for package level qualification and flight verification.

Recommended Action

1. Develop and baseline a government-approved Software CM Plan prior to baselining any FCF software. Ensure its compatibility with the government-approved and baselined MRDOC CM Plan. The two documents together must be capable of controlling the physical hardware and software configuration, not just drawings, documentation, and code. Ensure that the processes are put in place to manage changes that occur, subsequent to the baseline. Also ensure that an assessment is made to evaluate the validity of completed verifications.

2. Baseline software and place under configuration management prior to conducting package-level qualification testing, or verification test.

FCF-SW-010: CPU utilization

Statement of Concern

Analysis of amount of CPU time being utilized was not presented. This analysis needs to be done to verify that S/W will be capable of meeting all deadlines.

Recommended Action

All software (operating system, application, base classes, etc.) in each processor needs to have all tasks analyzed for schedule-ability via an established method, such as Rate Monotonic Analysis. Each task's frequency, priority, and amount of CPU time is needed to perform this analysis.

Actions:

1. Contractor to develop plan on how to do this analysis.

2. Plan to be approved by NASA.

3. In the event that the contractor chooses not to use Rate Monotonic Analysis, the Contractor is to provide a briefing to NASA on the method.

FCF-SW-011: Software Operational Aspects

Statement of Concern

The operational aspects of the software have not been defined. Without this definition, required capabilities may not exist in the software.

The operational aspects include:
1. Nominal operational sequencing.
2. Responses to off nominal measurements.
3. Loading of new software on board (FCF & Payload).
4. Ground commanding responsibilities, including FCF vs. Payload.
5. Data management on-board.

Recommended Action

1. Define and document the operational aspects of the software. The FCF Operations Plan, FCF-REQ-0063, Users Manual, and FCF Payload Accommodations Handbook may be logical places. This may require the assignment of a software engineer full time to investigate operational aspects and architect the software approach.

2. Confirm appropriate flow-down to software requirements documents.

3. Make sure that all software developers are familiar with these operational aspects.

FCF-SW-012: Users' Manuals

Statement of Concern

No approach presented regarding the development of FCF Users' Guide(s), documentation of how software works nominally, off-nominally, and its associated “features.”

Recommended Action

1. Assign responsibility and begin development of document(s).
2. Develop list of manuals.
3. RFA Initiator must agree with quality and completeness of manuals.

FCF-SW-013: Software schedules

Statement of Concern

The software schedules are inadequate to do real planning, to perform assessments of schedule risk, and to status the Government. The current, detailed software flight schedule lists 1972 tasks with (6-12 months level of effort) start to finish dates. Schedule is obviously done with copy/paste, making it unreliable. Schedule dependencies are often incorrect. There is not a reliable critical path report. Schedules lack critical schedule milestones, near-term activities leading up to milestone completion, links, or critical paths.

Fixing the schedule is a very high priority. Correct schedules are needed to manage critical path. Since FHA is close, it is imperative that accurate schedules are provided as soon as possible.

Recommended Action

The schedule documentation is tied to the WBS, which in turn was designed more for cost accounting than schedule. The contractor shall provide accurate, readable software schedules (one approach might be to specify schedules at higher WBS levels.) Clean up dates and durations to reflect real estimates. Add need dates, delivery dates, fix links, and show critical path items. Add test and integration milestones, along with preparation time, for FCF and payload integration. Add other applicable milestones and preparation. Add software system engineering efforts and testing (including hardware test support) schedules.

Provide CIR flight software critical path analysis. Provide integrated schedules with critical path analysis for FCF ground and flight software, and CIR software and hardware.

Complete this action as soon as possible.

FCF-SW-014: IV&V

Statement of Concern

The Board has concerns regarding:

1 The proper analysis of critical interfaces (end-to-end) relating to safety and other functionality.

2. Verification testing for critical requirements.

3. Testing of off-nominal, out-of-tolerance and safety related commands, data, communications, and methods.

Recommended Action

The Board recommends that an independent team verify:

1. All critical interfaces are consistent, complete, and satisfy all applicable higher-level communications requirements.

2. Verification testing provides adequate coverage on the critical requirements.

3. Safety requirements/hazards faults and failures have been adequately defined and tested.

FCF-SW-015: Ground software requirements and designs

Statement of Concern

Ground software requirements and designs are not mature enough to assess their adequacy.

Recommended Action

Define and document government software requirements and design. Conduct a peer/user table-top review of requirements by February 2003 and design by June 2003.

APPENDIX C - OPEN SOFTWARE RFAs FROM PRIOR REVIEWS

FCF-PDR-001: Document Software Development Environment

This RFA remains to be closed. As of December 5, 2002 the Contractor had not yet delivered their FCF-DOC-1111, FCF Software Development Environment. This document was to be part of the Contractor's data package for the FCF SW CDR, but was not delivered. The Contractor's explanation was that the document was almost ready, but could not be completed and baselined in time for the FCF SW CDR. It is expected shortly.

FCF-PDR-003: Hold separate FCF SW CDR

This RFA has been completed as evidenced by the review documented here. This RFA may now be closed.

APPENDIX D - REVIEW ITEM DISCREPANCIES (RIDs)

The dispositioned RIDs are supplied as an attachment to this report.

There are two RFAs to assure that the RIDs actions are completed and the RIDs closed. FCF-SW-001 covers the Type I RIDs while FCF-SW-002 covers the non-Type I RIDs

D.1 RID Disposition Process:

The process, led by the FCF SW CDR Review Team, included the scheduling of Contractor document author and RID initiator to be co-located (or where RID initiator was not at GRC, by teleconference) for each document submitted by the Contractor. The resulting meetings were also staffed by other Review Team members to aid in the disposition process.

Each RID contained, among other information, a Discrepancy and a Suggested Action. The RIDs, as dispositioned, were categorized as follows:

- The RID was considered “Accepted” if the document author agreed with the RID initiator’s suggested action to close the RID
- The RID was considered “Accepted with Modification” if the author and initiator agreed on alternate or modified wording for the RID closure action
- The RID was “Withdrawn” if the initiator deferred to an existing, disposed RID or had misunderstood the author’s document.
- The RID was “Disapproved” if the RID was out of scope, improper or otherwise not suitable and was not withdrawn by the initiator.

Each RID was also assigned a “Type” by agreement among the author, initiator, and Review Team

- Type I RIDs are those that have cost (greater than $15K) or critical path schedule impact and normally represent a significant change in design or planning
- Type II RIDs involve changes in design implementation or planning but do not impact cost or critical path schedule. Normally a Type II RID is of a technical nature and may require some additional design or analysis effort.
- Type III RIDs represent concerns or issues, which do not identify a deficiency in meeting project requirements or planning, but which should be corrected in future submittal of documentation, such as typographical errors, grammar, style, format, clarification, and other suggestions for improvement of the documentation.
- Type IV RIDs identify a missing document or other information that is necessary to demonstrate that the design is compliant with a particular requirement or set of requirements.

D.2 RID Disposition Metrics as of December 4, 2002:

By "Type":

(4) Type I*: All deal with tracking of targets during image processing with regards to target size, target speed, relative target size, and focusing requirements based design.
(45) Type II
(172) Type III
(191) Type IV
(45) Other (Withdrawn, disapproved or blank)

By "Category":

(188) Approved
(218) Approved with Modification
(42) Withdrawn
(2) Disapproved *
(1) Blank, un-disposed
(4) Type I, un-disposed

D.3 High Level Overview of RIDs by Subject:

- Requirement and design traceability and decomposition need improvement
- FCF-REQ-0063-FCF Software Requirements Document needs additional work to provide a home for software system requirements.
- Some systems level requirements are not available or decomposed for software

Note: David York entered eight RIDs (R-0219, R-0221, R-0222, R-0224, R-0228, R-0231, R-0234, and R-0236) on November 26, 2002 into the FCF CIR/FIR CDR RID entry database. The issues raised in these FCF systems level RIDs will be worked with Dennis Rohn, FCF Chief Engineer, and the Contractor to resolve the system/software issues. Other actions may be added as well to cover these issues.

APPENDIX E - ACRONYMS/ABBREVIATIONS

Acronym/Abbreviation	Definition
AI	Action Item
ARIS	Active Rack Isolation System
BPR	Biological and Physical Research
CDR	Critical Design Review
CIR	Combustion Integrated Rack
CMM	Capability Maturity Model from the Software Engineering Institute
CPAF	Cost Plus Award Fee (contract)
CSC	Computer Software Component
CSCI	Computer Software Control Item
CY	Calendar Year
D&DS	Diagnostics and Data Systems Branch
E&TS	Engineering and Technical Services Directorate
EDU	Engineering Design Unit
EM	Engineering Model
FCF	Fluids and Combustion Facility
FHA	Flight Hardware Availability
FIOP	FCF Input/Output Processor
FIR	Fluids Integrated Rack
FMEA	Failure Modes and Effects Analysis
FPIF	Fixed Price Incentive Firm (contract)
FSEB	Flight Software Engineering Branch
FW	Firmware
GIU	Ground Integration Unit
GRC	NASA Glenn Research Center
GSFC	NASA Goddard Space Flight Center
GUI	Graphical User Interface
ICD	Interface Control Document
ISS	International Space Station
IV&V	Independent Verification and Validation
JSC	NASA Johnson Space Center
KPA	Key Process Area in the CMM
KSC	NASA Kennedy Space Center
LMM	Light Microscopy Module
MDCA	Multi-User Droplet Combustion Apparatus

Acronym/Abbreviation	Definition
MOA	Memorandum of Understanding
MOBI	Microgravity Observations of Bubble Interaction
MRDOC	Microgravity Research, Development and Operations Contract
MSD	Microgravity Science Division
MSFC	NASA Marshall Space Flight Center
NGIT	Northrop Grumman Information Technology
ORU	Orbital Replacement Unit
OTS	Off-The-Shelf
PE&I	Payload Engineering and Integration
PI	Principal Investigator
PRACA	Problem Reporting and Corrective Action
PRCU	Payload Rack Checkout Unit
PTCU	Payload Training Center Unit
RFA	Request For Action
RID	Review Item Discrepancy
SAIC	Science Applications International Corporation
SARG	Standard Assurance Requirements and Guidelines
SATD	Safety and Assurance Technologies Directorate, Code 8000
SE&I	Systems Engineering and Integration Branch
SEPG	Software Engineering Process Group
SMDP	Software Management and Development Plans
S-POCCB	Space Station Payload Operations Configuration Control Board
SQA	Software Quality Assurance
SSC	Station Support Computer
STEP	Suitcase Test Environment for Payloads
SW	Software
TSC	Telescience Support Center
USA	United Space Alliance
V&TR	Verification and Test Review
V&V	Verification and Validation
WBS	Work Breakdown Structure